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Beetle Power

a look back at the origins of the VW engine by Edward Eves

This article first appeared in Autocar in the 1 May 1969 issue's VW Supplement. It is reproduced here with permission of that publication.

Born as a piece of political machinery the VW has been described as not so much a car as a way of life. It is powered by an unusual and expensive-to-make four-cylinder engine, air cooled with horizontally opposed cylinders. Capacity started at 985 cc. and has been almost doubled in the latest 411 model. Ferdinand Porsche investigated some interesting power units before this configuration was decided on. It is now a legend.

It is difficult but fascinating to try to unravel the very beginnings of the VW engine. It is easy to say that Karl Rabe and Xavier Reimspiess, under the direction of Ferdinand Porsche, designed a 985 cc horizontally-opposed, four-cylinder, fan-cooled engine to power Hitler's KdF-Wagen—strength-through-joy car. But the events that led up to this choice of configuration are tantalizing and obscure.

Long before Hitler came to power, Porsche, who had designed outstanding four- and six-cylinder Austro-Daimler water-cooled aero engines and then went on to design a four-cylinder twisted-boxer air-cooled engine for the same company in 1912, had been taken with the idea of streamlining as a means of saving power. As early as 1924, his business manager, racing driver Adolf Rosenberg, had raced the rear-engined Benz Tropfenwagen, which, in turn, had been inspired by the teardrop car built by Rumpler-Berlin in 1917.

Undoubtedly the Rumpler convinced Porsche about easy-to-propel streamlined cars, while his work on air-cooled aero engines which are essentially slow turning and reliable, with good torque at low revs, convinced him that this type of engine would be ideal to drive a low-drag car, given clear roads. The creation of the *autobahn* system fulfilled the latter requirement and the request from Hitler to design a People's Car gave him the chance to bring the low-drag, low-power car to fruition.

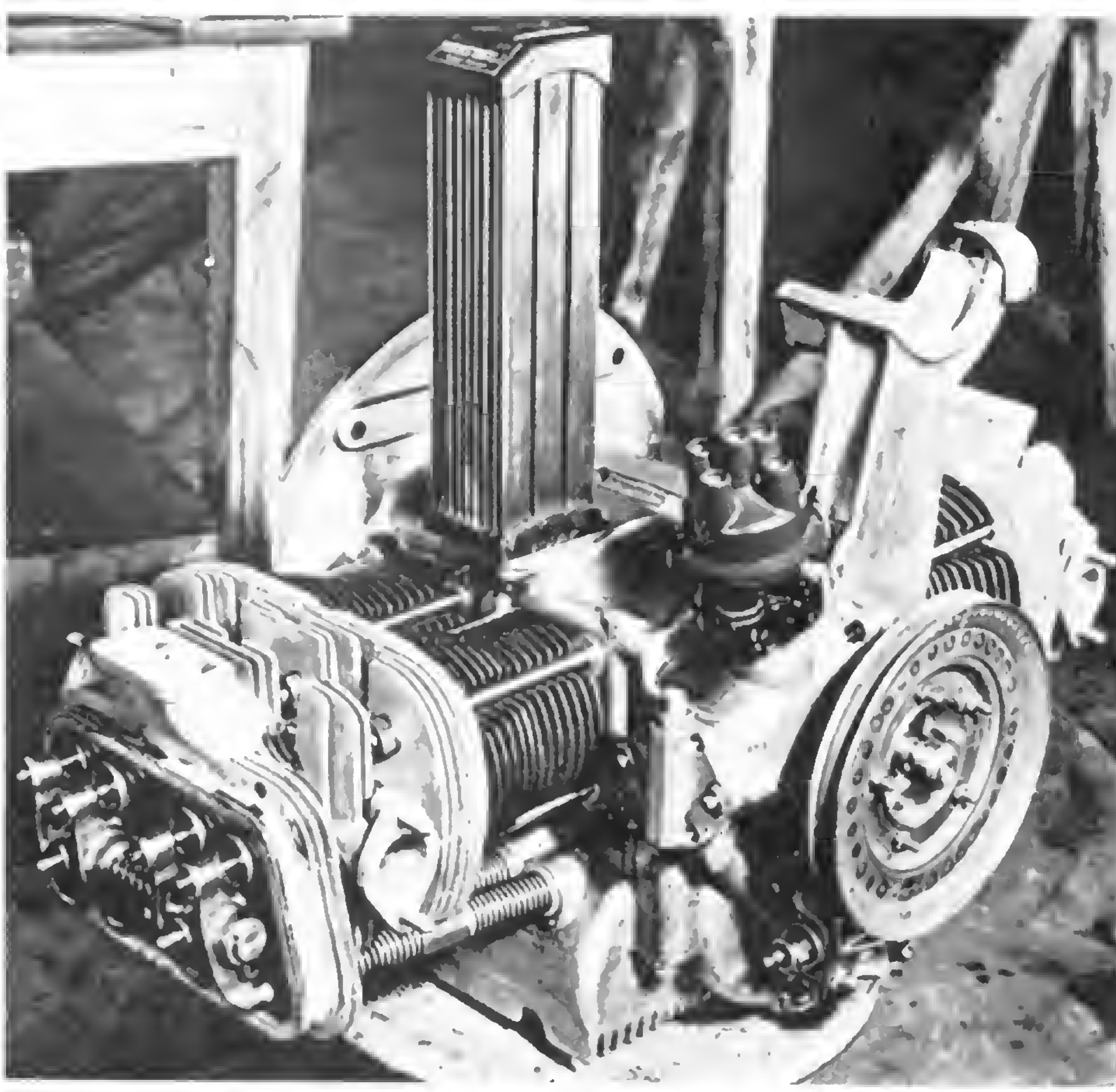
Very few designers produce a clear-cut design at their first attempts. Although Porsche had designed a 1500 cc horizontally opposed engine for NSU in 1933, a variety of engines was tried before the horizontally opposed four-cylinder configuration was chosen for the KdF-Wagen. Most mundane of the projects was a boxer-twin which was discarded on the grounds of lack of flexibility. The most interesting was a four-cylinder two-stroke in which two of the cylinders acted as pumps. It suffered from overheating, probably because there was no bulk of oil to carry heat away from the pistons. Most extraordinary was a twin-cylinder, single-sleeve-valve unit which had a habit of breaking the sleeve connecting rods, whereupon, as the ultimate triumph of hope over experience, Rabe tried to actuate the sleeves with cams and torsion bar springs.

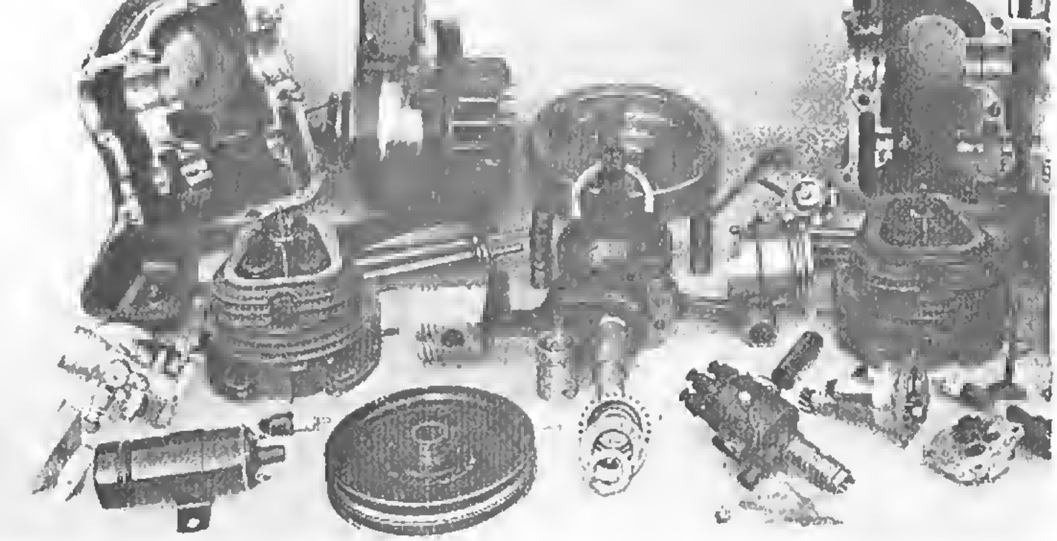
Development of these engines was stopped in 1936 in favor of the now classic air-cooled four. Cylinder dimensions of the prototype were fixed at 70 x 64 mm giving a capacity of 985 cc but only a limited number of these units were built—by Daimler Benz—as propellants for publicity cars used by the Nazi Party heirarchy. The 75 x 64 mm engine was developed for the military Kubelwagen-command cars and the fascinating Schwimmkubel, which were the only vehicles to be made in the Wolfsburg plant before peace broke out.

In the sparse post-war years the tooling for this engine was all that was available and was naturally used to produce the engines for early post-war Volkswagens.

Over the years the VW engine has changed only in detail. Short overall length and light weight were

Typical 1937 engine, first to have an oil cooler, differs little from the one which is well known to millions of postwar VW owners.





Components of twin-cylinder engine which was discarded for lack of flexibility. Like the other prototype VW engines, it was air-cooled. Note combined generator and fan. Distributor and fuel pump are similar to 1971 model.

and are main design parameters because of the need to reduce the polar moment of the car in view of the overhung rear engine position. It therefore has a magnesium crankcase and light alloy cylinder heads. The opposed cylinder layout keeps length to a minimum and the weight in the right place, low down. Designed in 1936 when 30 bhp was considered plenty, the crankshaft was indeed short of bearing area if attempts were made to produce more power as some tuners found to their cost. The major power increments in the VW coincide with the availability of high-duty bearing material and in 1961 by an increase in the length of the crankshaft.

Rigidity was increased by extending the crankshaft, and supporting the nose in what is effectively a fourth main-bearing. The timing gears and the distributor skew gear are mounted on the section of shaft inside the chamber and the fan pulley externally on the end of it. The crankcase is split vertically, each half including half of the bearing-housings for the crankshaft and camshaft. The two halves are tied together with long studs passing horizontally through the bearing saddles and by nuts and bolts at the flanges. Although this construction precludes removing the sump, which is part of the casting, cleaning is no longer a problem with modern oils and the layout makes for a very rigid crankcase. An inspection plate is provided in the bottom of the sump through which some cleaning can take place.

Separate cast-iron cylinders are used with one-piece aluminum heads, the whole assembly being held down, motorcycle fashion, with long studs, eight per side, tapped into the crankcase. The unusual port layout, with vertical inlet tracts and with the exhaust ports coming out of the ends of the heads, is necessary to maintain exhaust-pipe ground clearance and also allows the push-rods—the camshaft is located under the crankshaft—an unobstructed passage to the valve gear. Oil return from the rocker covers is by way of the push-rod tubes which are inclined, to hasten drainage. Pressed-steel rocker covers retained by wire clips seal the rocker chambers which are partly formed in the cylinder head castings.

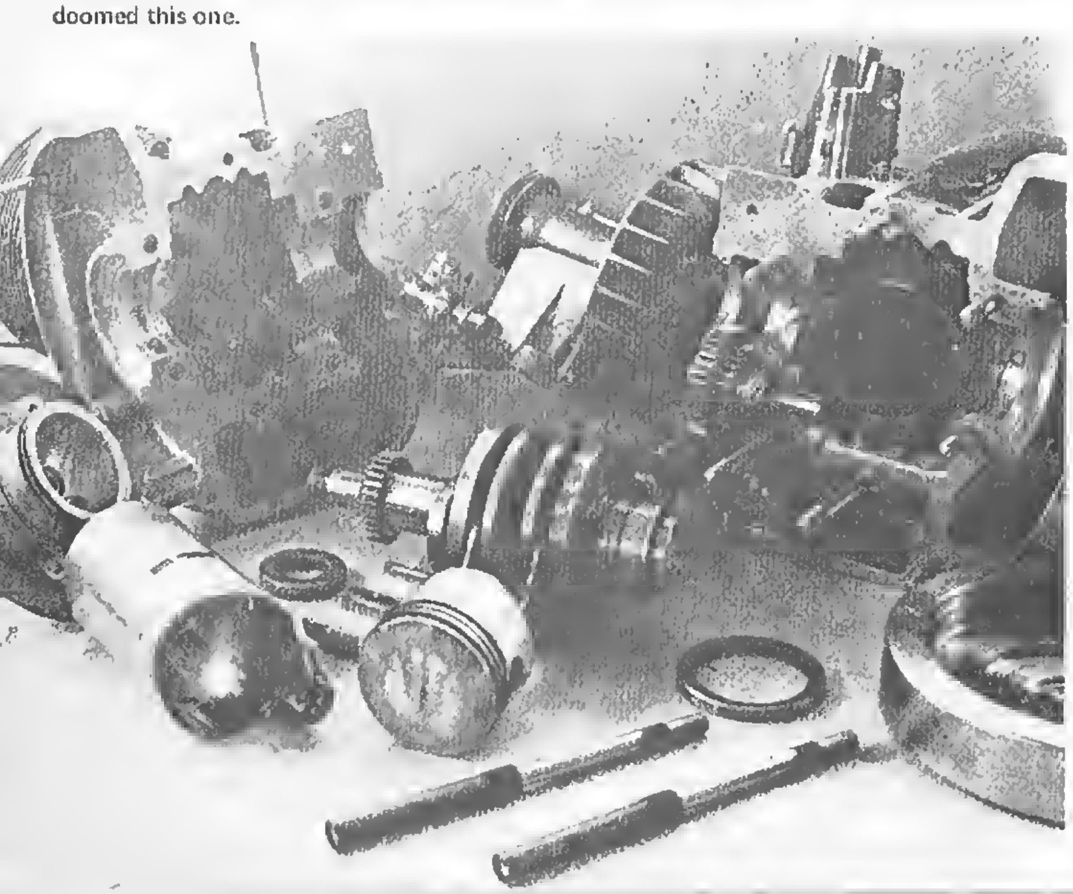
With these slow-running engines long accelerating and decelerating ramps are not required on the cams, so the valve tuning appears less extreme than it really is.

The early 1,130 engines had inlet tuning of 2.5° and 37.5° for the exhaust. This was opened out to 6.5° (inlet) and 42.5° (exhaust) on the 34 bhp, 1,192 cc model. As a comparison the latest 411 engine has inlet and exhaust openings of 4.5° and 40.5° respectively.

Combustion-chamber shape is exceptional these days in being a quite straightforward truncated pent-roof type with the valves almost parallel with the cylinder axis but offset slightly below it. Early engines had flat-top pistons giving a compression ratio of 5.8 to 1 deference to the low-octane fuel then available; the latest 1300 has pistons giving a ratio of 6.8 to 1.

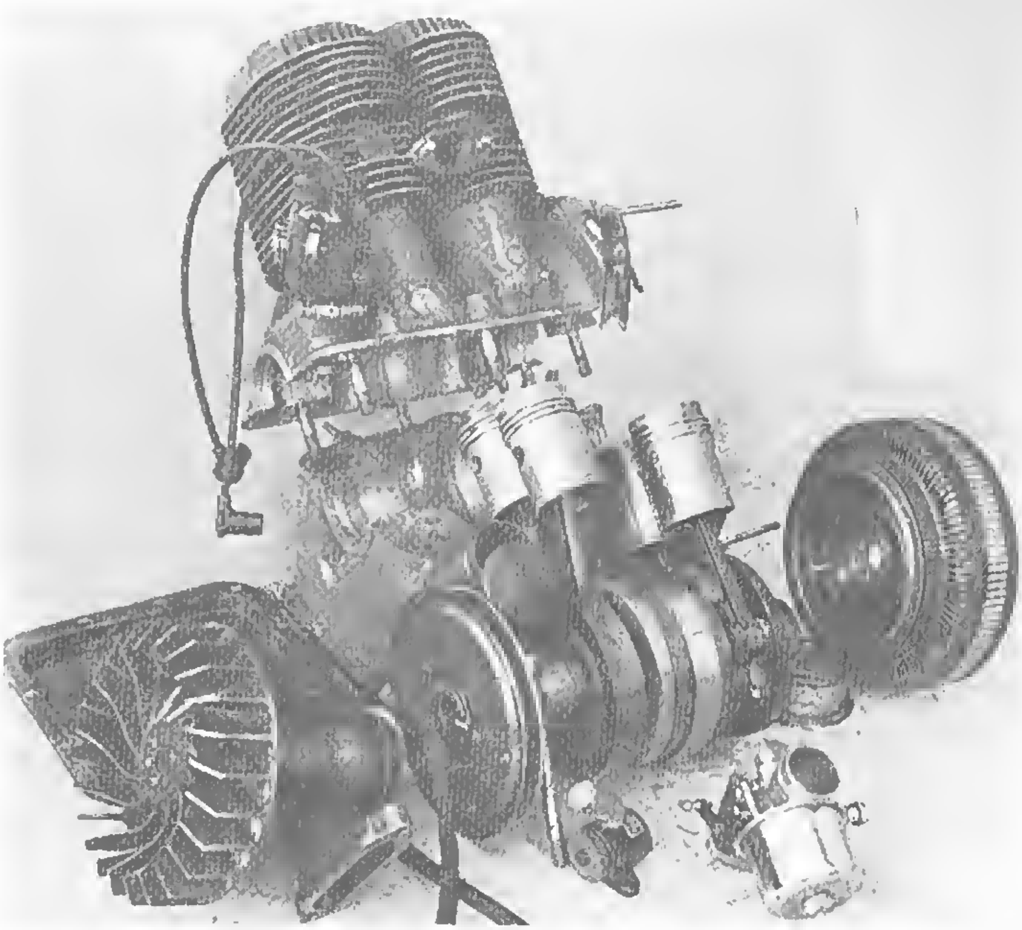
Lubrication is by a gear-type pump driven off the end of the camshaft. From the beginning the VW has had an oil cooler mounted in the cooling shroud. Porsche no doubt deduced from his experience with the two-stroke prototype, that

Prior to World War II, many engineers worked on sleeve-valve engines. Here's Porsche's attempt—a twin-cylinder model with cam-operated sleeves closed by torsion bars. Cam is next to the gear end of the full-circle roller-bearing crankshaft. Excessive sleeve friction doomed this one.



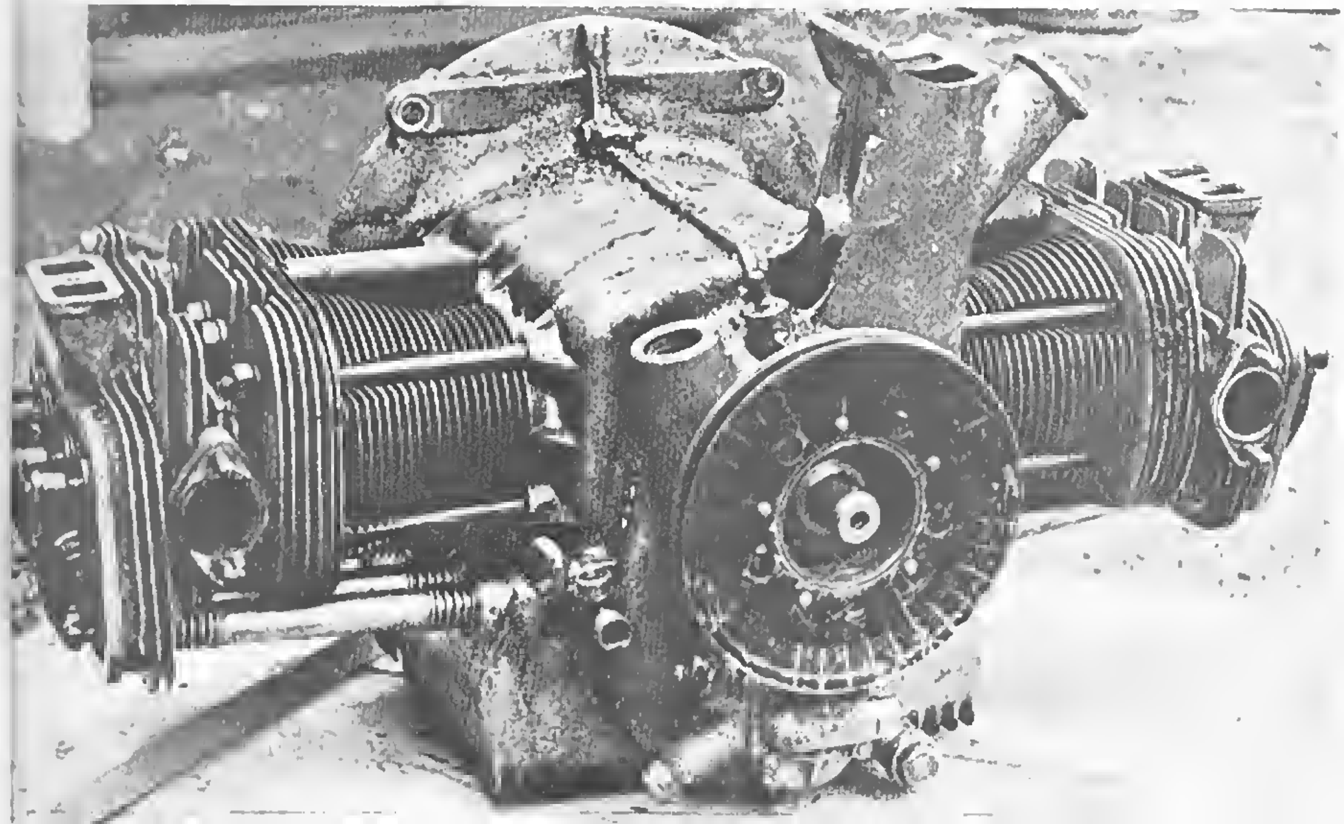
an air-cooled engine mounted at the back of the car, out of the airstream, must dispose of some heat by way of the lubricating oil. This is born out by the Porsche racing cars which have oil-coolers almost as big as the coolant radiator of a liquid-cooled engine.

On all early engines, and on most of the latest ones, mixture is supplied by a single carburetor, of Solex manufacture, mounted on an exhaust-heated manifold fabricated from steel tube. This manifold is so like a pair of sit-up-and-beg bicycle handlebars that one British engineer on seeing it remarked that he supposed the sports model had a fully dropped manifold. To eliminate icing and to evaporate loose fuel the manifold hot spot extends almost a third of the length of the horizontal section of the manifold and consists of a steel tube siamesed to the main tube by welding. An early attempt to make an exhaust heated jacket—it was fitted on early 1,192 cc cars—ended in failure. The exhaust gas burnt through the inlet manifold, thoroughly upsetting the carburetion and many thousands of manifolds had to be replaced by the old type, which is still used.



Technically minded readers will be excited by this one, a four-cylinder two-stroke with two cylinders supercharging the other two—discarded for overheating. Combined starter and generator on right. Two-stroke fans will note the full-circle crank with crankcase-stuffer blocks.

A very few of these engines were built for powering Nazi party show cars. Looks similar to the 1100 cc engine.



At one time it was considered inadvisable to fit twin-carburetors to standard VW engines, probably because of the marginal bearing loadings. But the 1500, 1600 and 411 engines do not suffer from this shortcoming. The latest carburetor types for the 1600 and 411 are Solex 32 PDSIT and the Solex 34 PDSIT respectively. 1300 and 1500 Beetles use the Solex H30 PIC and the Solex 30 PICT.

Porsche experimented with cast-iron crankshafts in the prototype stage and they broke, since when all VWs have had forged crankshafts. The connecting rods are likewise steel forgings, split at right angles with fully floating piston pins and diecast light-alloy pistons.

Cooling air is circulated by a centrifugal fan supported by a cast bracket on the crankcase and working in a sheet-metal housing on top of the engine. The amount of air passing through the fan is regulated by thermostatic control. Vanes inside the duct split the air equally between the two cylinder banks. Flap valves in the exit duct below the cylinder allow part of the waste hot air to be channelled to jackets surrounding the exhaust pipes, where it is heated further and fed into the car heating system.

When Porsche showed his proposals for this power unit for the KdF-Wagen in 1936, established German manufacturers threw up their hands and said "this aircraft engine" could never be made for the price. Any production engineer would say the same today if he didn't know that VW production tooling had not only made the whole thing possible but had made it an extremely worthwhile proposition.

The People's Car

unknown to most people, the original People's Car was intended by Hitler t[o] be a military machine of high efficien[cy]

by O. G. W. Fersen

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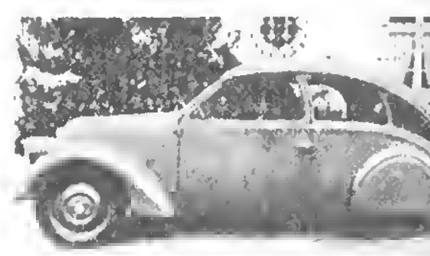
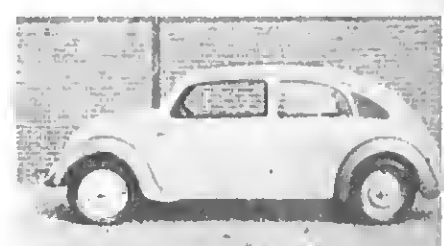
Never before has a car been designed under such extraordinary conditions and in all probability never will be again. The people's car was born by order of a dictator—disregarding cost and commercial reason—and it was going to be built by the Nazi labor front, a kind of state-managed union. It would perhaps never have materialized but for a human comedy and when it seemed utterly dead after the war had left its breeding place in shambles, a British colonel revived the Beetle. After this it went from strength to strength, provided the first four-wheeled private transport in postwar Germany and captured the American market in a way no other manufacturer has been able to match.

The original Porsche design became a kind of creed for the Wolfsburg empire, that even its own leading technicians did not dare to question. Now it seems that its days a[re] coming to a close, although there is ev[ery] indication that it will go on in manufa[c]ture for many years to come.

The car wo[rld] knows only a small number of classic designs that have lasted in manufactur[e] basically unchanged—for 10, 20 or 30 years, the Ford-T, the *traction-avant* Citroen, the Volkswagen and the Mini. All of them were and are highly origin[al] designs and it seems significant that th[ey] all stem from men who were not quali[fied] engineers in the accepted way. The st[ory] of the Beetle starts on February 11, 19[33]



Porsche experimental car built for Zundapp in 1932



Porsche experimental prototype built for NSU in 1933-34

After assuming power, Adolf Hitler declared at the Berlin Motor Show tha[t] Germany was to build a cheap-to-run small automobile to "motorize the people." Jacko Werlin, former Merced[es] Benz dealer in Munich and then Hitler's aide for all questions on motoring, arranged for a meeting of his boss with Ferdinand Porsche. The latter, after

One of three "60" series prototypes pre-production. Note the absence of a rear window.

working as a chief designer and techr director for Steyr in Austria and Dai Benz in Germany, had set up as an independent designer two years earlier. At Stuttgart he ran his own engineering business. Werlin knew Porsche and a while ago had discussed with him a plan for a small car which now seemed to fit admirably Hitler's ideas.

Porsche's team included Younf Bela Berenyi and engineers Rabe and Kales. At the age of 26 Berenyi had done a study design of a small car with a backbone frame and an air-cooled "flat-four" rear engine. Also Kales had designed a rear-engined small car before joining Porsche's team. As Porsche himself had at the time just taken out patents for torsion-bar suspension, it seemed obvious that this "background" was to have some influence on the car to be designed.

When Ferdinand Porsche was summoned to see Hitler, his people's car concept was far beyond the pipedream stage already. Of his own initiative, and with very limited means, he had starred what was called "Project No. 12." As later the Zundapp and NSU companies had shown interest in the car, a number of prototypes were built between 1931 and 1939, first for Zundapp and then for NSU. The first of them was powered by a radial five-cylinder engine. Also a three-cylinder unit was tried but when the company ran out of funds, Porsche looked for another sponsor. This time NSU stepped in and another batch of cars were built this time with 1.5-litre flat-four engines. After extensive development work NSU found out that they could not enter car manufacture at all, because they had signed a contract forbidding them to do so, when they sold their Heilbronn plant to the Fiat company.

A second series "60" prototype built by Daimler Benz in 1937

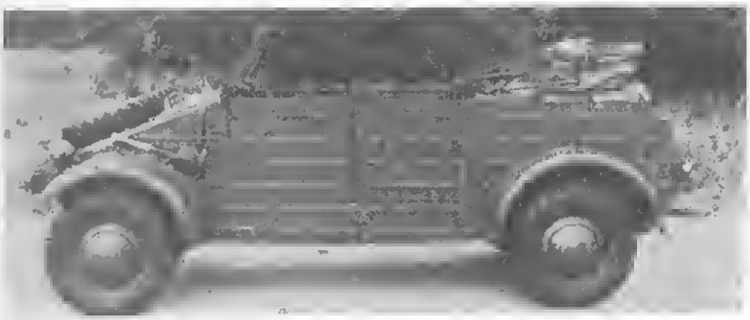
Hitler lays the foundation stone of the Volkswagen factory in 1938, by which time the Beetle as we know it had already taken shape

In his interview with Porsche, Hitler put forward demands for the people's car that stunned Porsche: The car had to be able to cruise at 60 mph, fuel consumption was not to exceed 40 mpg, the engine was to be air-cooled, the body was to provide room for five people and the complete car was to be priced at less than 1,000 marks, retail.

Perhaps Porsche would have turned down the suggestion altogether, as the price demanded seemed utterly unrealistic to him. Also there was no plant in existence where the car could have been manufactured in the envisaged numbers. All the questions however were answered during a two-act comedy whose involuntary chief actor was Wilhelm von Opel, then member of the board of the GM-owned Opelwerke. Opel first teased Porsche to accept the offer, make a lot of money and then turn down the thing as an impossibility. Porsche felt hurt in his pride—and accepted the challenge. The "second act" came about at the 1937 Berlin Motor Show when Opel—who knew that only Opel and Ford had the plants in Germany to build Hitler's car—greeted the dictator at the stand of his firm and proudly presented the Opel P4. A small saloon of conventional design offered at the then sensational figure of 1450 marks with the words: "Mein Fuhrer, look here, this is our Volkswagen," upon which a furious Hitler abruptly turned and marched away. A few days later Deutsche Arbeitsfront was summoned to build a factory solely for the manufacture of the people's car—or KdF-Wagen, as it was then called. Wolfsburg was chosen as a site.

With almost unlimited funds Porsche was now able to realize his dreams. Chassis and body of the beetle-shaped car did not seem to present any problems but the engine gave the designers quite a few headaches. Porsche himself was in favor of a two-stroke unit because of its simplicity and good low-speed torque. Inside 20 months no fewer than a dozen different engines were designed and built. Twin-cylinders and flat-fours, engines with poppet—and with sleeve-valves, and a number of two-stroke units. Fascinated by the double-piston engine of the Austrian Puch motorcycle, Porsche's pet was a vertical double-twin two-stroke. This engine gave good torque but the thermal problems seemed insurmountable. It did not stand sustained high speeds. When time began to run short, Porsche reverted to a flat four designed by Kales in 1933. This engine became the grandfather of the Beetle's heart, as we know it today. Porsche, not satisfied with this decision, promised to have it replaced by a two-stroke engine no later than 1944.

In February 1939 the KdF-Wagen was officially presented at the Berlin Motor Show. The writer, then visiting the "IAMA" as a foreign motoring correspondent, was privileged to have a brief run in the Beetle on the Avus track. The little car did look very "cheap" with quite a lot of exposed sheetmetal in the interior and an engine that no one could call refined. But after all, it was a full-



Type 82 military vehicle with bored out 1,130 c.c. engine giving 25 bhp

Type 166 amphibious VW with four-wheel-drive

sized car and it cost less than 1,000 marks, or as much as a medium-size motorbike. This sounded incredible.

In the light of later knowledge some of the unusual design features seem quite logical, because the car was designed with Hitler already aiming at his later military exploits. Its engine was to be cooled by air to be able to operate in climates where water might be scarce or temperatures extreme. The choice of a rear engine had less to do with refinements of roadholding than traction off the beaten track. The people's car quite obviously was designed as a military machine of high efficiency. For war service the engine capacity was increased from 985 to 1,130 cc which upped power from 23 to 25 bhp. 70,000 military Volkswagens were built, 1,500 of them amphibious Beetles.

In 1945, the history of the German people's car seemed to have come to a definite end. It was a British Army officer who set the ball rolling again. First he permitted the assembly of a few cars from salvaged parts, then actively aided in setting the wheels of production into motion again. Thus under British command 713 Volkswagens were built in 1945 and after this, rehabilitation proceeded in big strides: Ten years later, in 1955, the millionth Volkswagen rolled off the assembly lines.

The enormous success of the Beetle in the post-war world is not difficult to explain. The question of ownership of the vast Wolfsburg plant remained in suspense for a number of years. During this time there were no shareholders to demand dividends and the boom of the quickly recovering economy provided a world-wide sellers' market. Profits were ploughed back into expansion and modernization of the works. Heinz Nordhoff, shrewd man at the top of the Volkswagen empire, stubbornly refused to replace the Beetle by a more modern design, but ordered brass and brains to concentrate on detail-improvement. A servicing organization second to none was built up. Thus the Beetle grew up in a kind of gentle hothouse climate, whereas competitors all over the world had to grapple with all kinds of problems.

Today, it seems, the Beetle is confronted with the old problem of classic designs: It cannot be improved or changed. When it has lasted its time, one day, a new car will have to replace the now 35 years old Porsche Beetle. It seems unlikely that any successor could be as advanced again as the Volkswagen was in its youth—to last a production age now beginning to approach a quarter of a century.

One of the earliest sporting VWs was this home-built special, with aerodynamic body and Plexiglas cockpit cover, of 1948

Just post-war, a 1946 model with opening front bonnet and twin rear windows

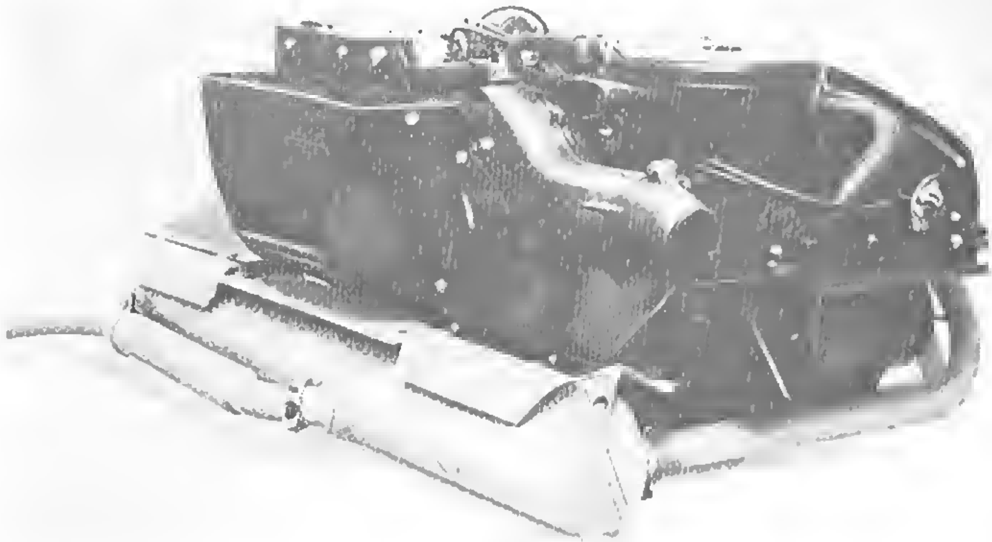
VW engines all alike? Hardly!

The beginning VW enthusiast looks at a pile of VW engines in the junkyard and they all look alike. But, they're not. In fact, some are barely similar. So, if you are getting an engine for use in dune buggy or other special vehicle—or a replacement—or want to start wrenching on an extra engine so you can keep your transportation intact—you'll want to know which engines to buy and which ones might best be avoided.

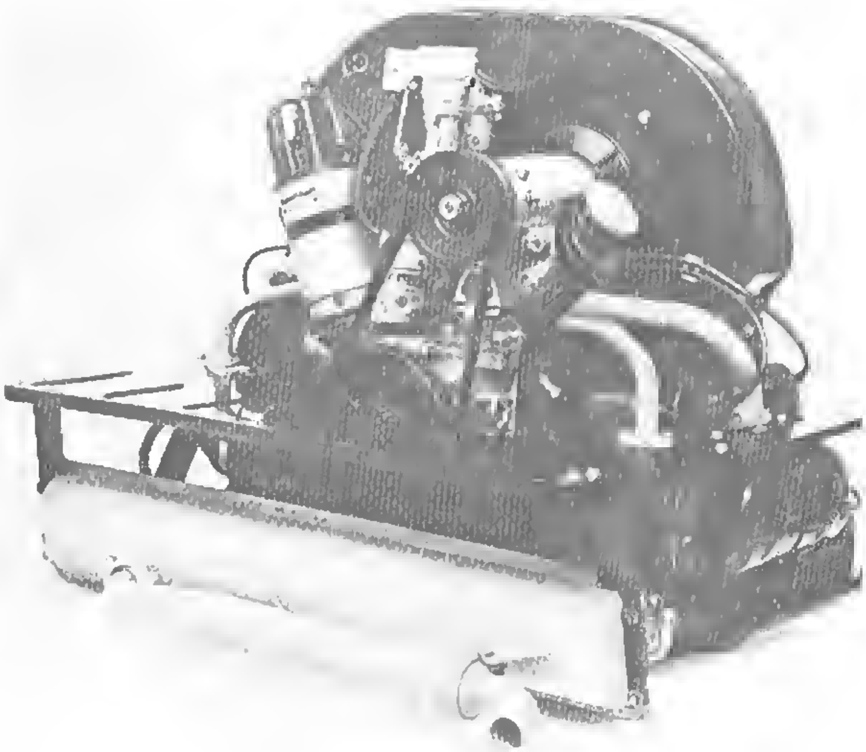
The most widely available engine may be the ones to avoid, regardless of their seemingly low price. Although we have not devoted any other space to the 36 HP engine used from 1954 through 1960, this section analyzes that engine. After all, you may own one and have an undying love affair going with it. We'll just describe the warts and pimples and you can decide whether you can live with them. Some of the other engines have problems, too, and some of those are spotlighted to aid your decision.

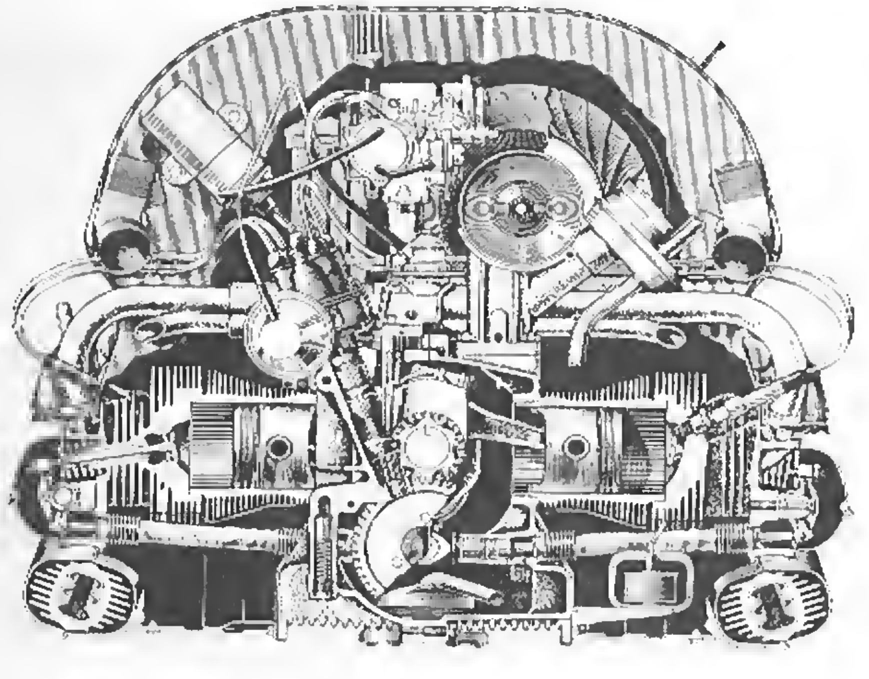
Problem areas may keep you from investing a lot of money in an engine which could better be sold or scrapped in favor of a later model—requiring less expenditure for the performance application, even after adding on the cost for the engine.

36 HP Engine, 1954-60, 1192 cc
Use: All VW vehicles 1954-59, 1960 beetle. Serial nos. to 5,000,000.
Identification: Generator bracket is part of right side of crankcase casting.
You should know: Well made: good materials and workmanship. Fiber cam gear (weak point) can be replaced with aluminum one. Cranks often broke in these models, often from excess spark advance. Nos. 1 and 2 main bearings pounded so hard by flexible crankshaft that bearing bores in case assume oval shape. Valves often failed under head. Cam rides directly on case bores. Fabulous engine when left alone. One of the best years in terms of quality and materials was the 1958. Best thing to do with 36 HP engine is to leave it alone and run it in its stock condition. If you insist on hotrodding it, life will be short. Available hotrod parts include SPG roller crank (same as early Porsche), intake manifold for center

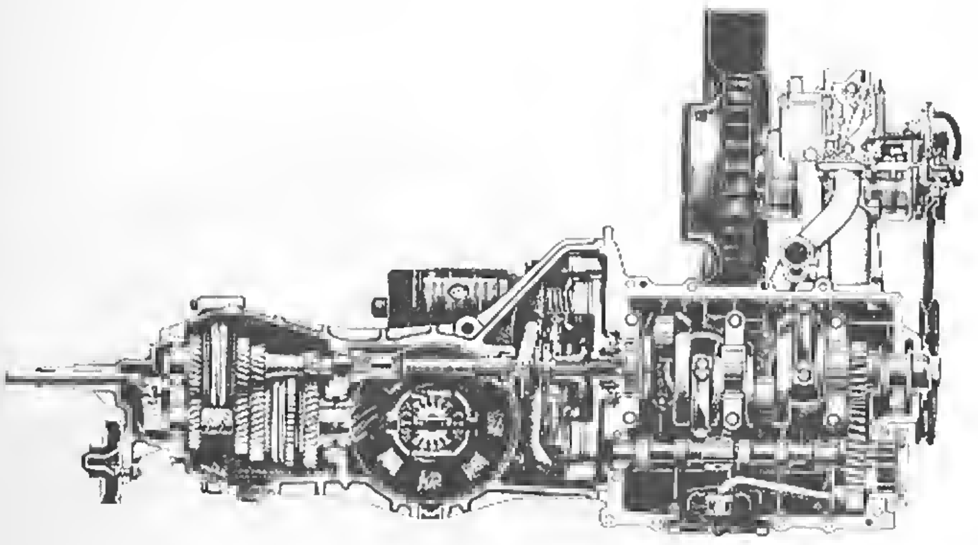


Lots of VW engines are sold for industrial uses. Model 124A (top) is based on low-profile "flat-fan" engine used in Fastback/Squareback, develops 53 HP at 3,600 RPM. Lower engine is similar to VW beetle engine, develops 40 HP at 3,600 RPM. Note magneto ignition.





Air-cooled engine used in 1970 beetle, Ghia, and trucks and busses develops 57 HP at 4,400 RPM from 1,584 cc displacement.



two-barrel, exhaust system . . . none of which should even be considered because they dramatically hasten the destruction of the engine. You'll be money ahead to start with a 1966 1300 or later/larger engine with replaceable cam bearings.

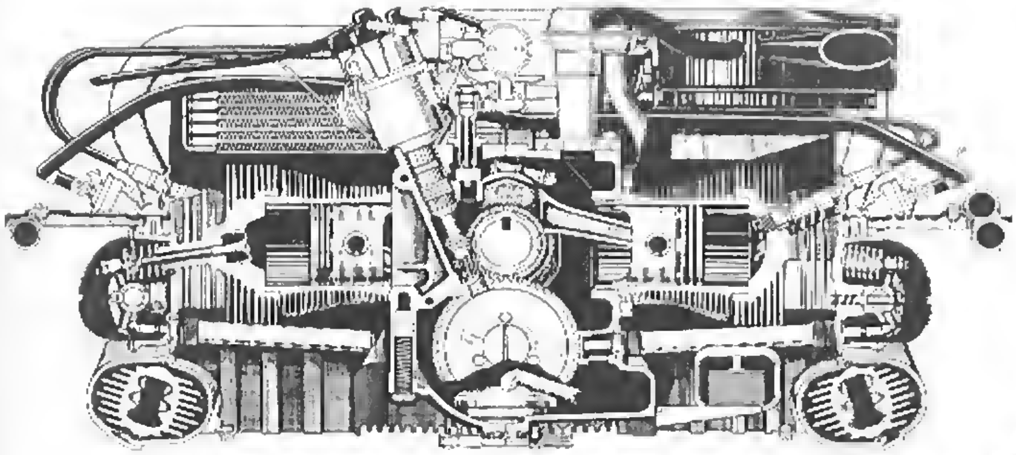
40 HP Engine, 1192 cc
Use: 1960-63 1/2 Type 2 from serial 3,500,000. Type 1 1961-65.
Identification: Single center-mounted carb with electric choke, generator bracket bolts on. Intake manifold joins head at right angle.
You should know: This is probably the first type engine that a junkyard will try to sell you unless they have a yard full of 36 HP engines. 1960-61 models had poor tappets and camshaft material compatibility which gave trouble. Cam runs directly in case bores. When clearance gets great, oil pressure goes away, demolishing rod bearings. Cases can be modified for later-style cam-bearing inserts. Models with long rocker-arm studs extending through rocker-box floor of head to screw in by combustion chamber often leak oil and long rocker studs often break. Long studs can be replaced with repair kit containing short studs, but this won't eliminate tendency to crack between plug hole and valve seats. Even if heads not cracked you should plan to replace guides and all valves. These engines also suffered from broken-crank syndrome.

A 37.5 HP engine used on some Type 2 vehicles in 1959 is rare and you are not apt to find one, but if you do, it has a removable generator stand and takes clutch thrust at the No. 2 main bearing instead of No. 1.

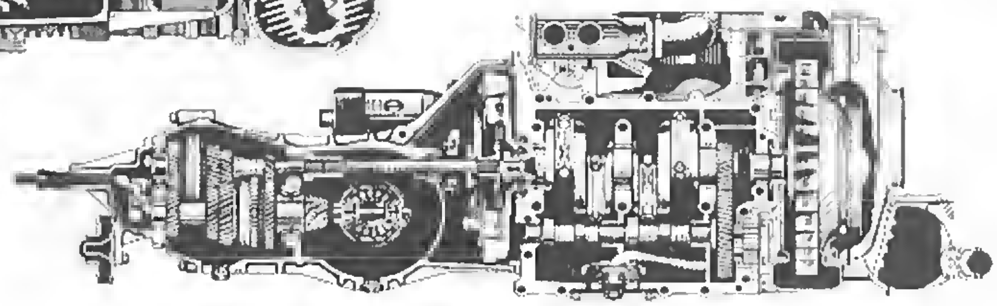
Don't buy a used 40 HP engine if you can afford a 1966 1300 or later/larger engine.

51/53/66 HP Engines, 1493 cc
Use: 1963-1/2 through 1965 Type 2, 1962-65 Type 3 (flat engine).
Identification: Case has different webbing inside and at No. 3 main on outside. Intake manifold joins head at 20^0 angle. Dual carbs on 64-65 flat engines.
You should know: This is a bored and stroked 40 HP engine with all of the 40 HP's problems. There are no insert cam bearings, piston pins are 22 mm, and the heads will have larger valves in the engine used in the Type 3 vehicles.

50 HP Engine, 1285 cc
Use: 1966 beetle only.
Identification: Intake manifold joins head at an angle, 30 PICT carburetor, bore and stroke. F in front of engine serial no.
You should know: Especially good engine because it has insert cam bearings and the 0.200-inch-longer crankshaft stroke. Short rocker studs and better head material make these heads less subject to failure than earlier models. Engine easily converts into 1500 or 1600—or larger engine—by installing larger cylinders. Case does not have to be bored out to fit 1500/1600 cylinders, but heads must be bored out because tops of cylinders are larger. Rods are longer than earlier models, giving better rod angle, and self-aligning caps on rods are also an improvement. 22 mm piston pins instead of 20 mm used in 36 and 40 HP.



Cutaway drawings of 1970 Fastback/Squareback fuel-injected 1,584 cc engine which develops 65 HP at 4,600 RPM. Drawings courtesy VW of America.



53 HP Engine, 1493 cc
Use: 1966-67 Type 2, 1967-69 Type 1
Identification: Intake manifold joins head at angle, 130-tooth flywheel on 12V models. H in front of engine serial no.
You should know: Good engine for any application.

57/60/65 HP Engines, 1584 cc
Use: 1970-71 Type 1, 1968-71 Type 2, 1966-71 Type 3 (flat engines)
Identification: Engines through 70 models have B in front of engine serial no., except fuel-injected flat engines which have U in the serial and two-carb flat engines which have a T (both with dual-port heads). 1971 Type 1, 2 vehicles have redesigned fan housing and cast-aluminum adapters at dual-port heads to mate with single-tube manifold.
You should know: 1970-71 engines with larger oil passages in crankcase, identified by two oil-pressure relief valves, are best engines made to date. If you buy a fuel-injected engine, get all of the F.I. parts and stock cabling harness, most of which mount separately from the engine: fuel pump, computer, pressure sensor, pressure switch (not on all models) and relays.

ENGINE DATA CHART

Model Year	BHP SAE	BHP DIN	Displacement Cu. Cm.	Displacement Cu. In.	Engine Code Letter	Compression Ratio
Sedan & Karmann Ghia - Type 1						
1945	30	25	1131	69.02	-----	5.8
1953	36	30	1192	72.74	-----	6.1
1954	36	30	1192	72.74	A	6.6
1961	40	34	1192	72.74	D	7.0
1966	50	40	1285	78.42	F	7.3
1967	53	44	1493	91.10	H	7.5
1970	57	47	1584	96.66	B	7.5
1971	60	50	1584	96.66	-----	7.5
Station Wagon (Bus) & Truck (Transporter) - Type 2						
1949	30	25	1131	69.02	-----	5.8
1953	36	30	1192	72.74	-----	6.1
1954	36	30	1192	72.74	A	6.6
1961	40	34	1192	72.74	D	7.0
1963½	51	42	1493	91.10	G	7.8
1966	53	44	1493	91.10	H	7.5
1968	57	47	1584	96.66	B	7.5
1971	60	50	1584	96.66	-----	7.5
Fastback/Squareback/Notchback - Type 3						
1962[1]	53	44	1493	91.10	K	7.2
1964[2]	66	54	1493	91.10	R	8.5
1966[2]	65	54	1584	96.66	T	7.7
1968[3]	65	54	1584	96.66	U	7.7

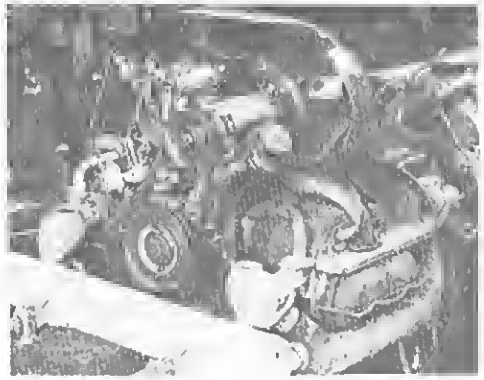
1 - one carburetor 2 - two carburetors 3 - fuel injection

Displacement - Bore X Stroke

1130 cc - 75 X 64 mm, 2.93 X 2.52 in.
1192 cc - 77 X 64 mm, 3.03 X 2.52 in.
1285 cc - 77 X 69 mm, 3.03 X 2.72 in.
1493 cc - 83 X 69 mm, 3.27 X 2.72 in.
1584 cc - 85.5 X 69 mm, 3.37 X 2.72 in.

Bolt-on horsepower

a lot can be done without taking your engine apart



1500 cc engine used as our base for tests on improving performance with bolt-ons.

If you have a VW engine that is running well—and have no desire to race your beetle—chances are you'd like to know what can be done to get more out of the engine without taking it apart completely. How about 77.5 HP from a 1500 cc VW with bolt-on equipment? Does that 31.5 HP increase sound interesting? What's a "bolt-on?" That's a modification which can be accomplished without splitting the crankcase. When you start talking about changing crankshafts and camshafts or installing cylinders which require boring the case—you are out of the bolt-on category. You should not be concerned about having to take the engine out of the car to do simple things such as head modifications because it is so much easier to work on the engine when it is where you can get at it without making like the proverbial India Rubber Man.

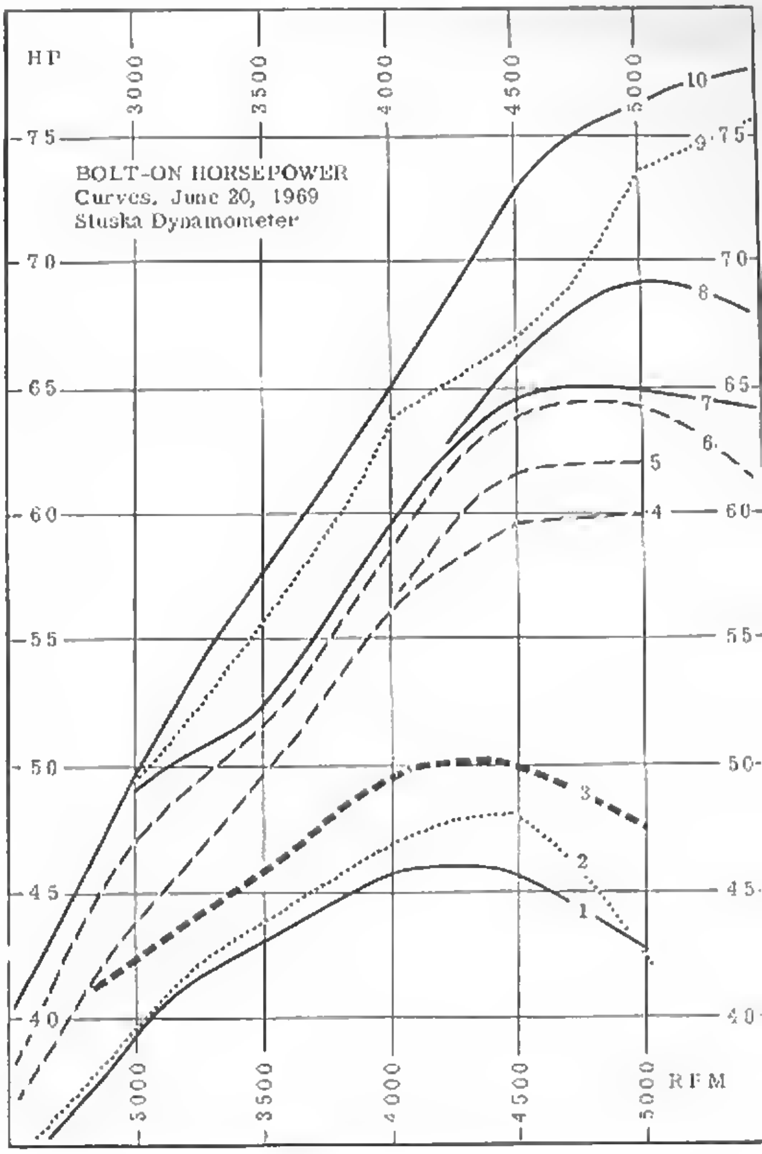
What kind of bolt-ons did we try? First the exhaust system, secondly a minor change to the carburetion with jet changes and blocking off the manifold heat. Thirdly, we changed the intake manifold for a different type using the Holley carburetor, and added a mechanical-advance Bosch distributor. Here we were helped by Holley Application Engineer Don Gonyon who came equipped with a pilot-run model of the Holley Bug Spray. Next we changed the stock crankshaft pulley for one with a smaller diameter and then added a set of 1.4:1 forged-steel high-lift rocker arms—EMPI's, of course. Finally, we took the heads off and flycut them for more compression—cleaned up the ports and swapped the valve springs for some new heavy-duty ones. As you can see, the changes which were made could be duplicated without even taking the engine out of the car—at least not until the cylinder head work. The cylinder-head work would have undoubtedly added more horses had we run air-flow tests (described in the Cylinder Head chapter) beforehand. I think that these changes should really appeal to the fellow who wants more beans from his beetle for charging back and forth to work on the freeway or for weekend jaunts on back roads. I also believe that these modifications are the absolute limit of what you should consider putting into or on your VW engine until you can split the case to do the rest of the work which is required to keep the flywheel mated to the crankshaft—specifically, more dowels. These are essential to keep the flywheel from making a mess of itself and the crank.

One of the things which you may appreciate if you've been frustrated (as I have) by magazine articles which compare apples and oranges, is the fact that my tests began with one particular engine and then changes were made in a progressive way. Every item's contribution to the ultimate power which was obtained can be identified. You can see what caused what to happen. *I tried to keep comparing oranges with oranges—instead of with pears, grapes, pineapples or whatever.* Too often, writers and engine builders get in a hurry to meet a publication deadline for a story and they make two or more changes at once. You should be immediately suspicious when you read such stuff because you can't, no matter how hard you try, figure out which item or change was needed. You should then wonder whether someone is trying to pull the wool over your eyes. The engine is not the only part of the VW that demands the bolt-on approach. The suspension must be looked after, regardless of whether yours is a swing-axle or four-joint rear end or a trailing-arm or Macpherson-strut front suspension. As explained in the Handling chapter, the problem of stability or a lack of it is caused by a combination of aerodynamic and suspension effects. For utmost safety, you would be wise to consider the suspension bolt-ons prior to doing anything to the engine. The stock VW engine can push you fast enough to get you into serious trouble—especially in an unfriendly cross-wind, or even in gusty head-wind conditions.

Bolting EMPI high-lift (1.4:1) rockers onto the test engine added 3 HP in test 5. and subsequent tests. See HP graph.

WHAT'S THE COST OF ALL THIS?

If you were to guess at the investment represented in a top-performing street engine—or for an all-out off-road, circle-track or drag-racing engine—you'd probably be 'way under the actual costs. Figure about $1,200 for building a "right-on" street engine—and close to $1,800 for a racing engine . . . that's with you supplying a usable "core" engine, and Weber carbs cost extra on top of those figures, too. For a spare engine, double the figure and have another core handy. If you've priced a factory-rebuilt engine from Volkswagen, you know that you can get out the door for under $400—with all of the new parts and warranties that come with a VW-rebuilt engine—so why should an engine rebuilt for speed and power cost almost as much as a new VW? Until you've done all the nitty-gritty work yourself, it is literally impossible to imagine the time which is eaten up in the nit-picking details of modifying the parts, getting various pieces balanced, Magnafluxed, glass-blasted and all the rest . . . plus the prices for the forged pistons and special cylinders, roller crankshaft, "flowed" heads and all the rest. If you are the type that gets "all up tight" about the cost of anything whatsoever, don't go racing because your life will become just one miserable incident after another. Engines do blow up. And they cost money to rebuild the second time, and the third time, and the fourth. It's better that you should know this *and believe it* before starting, otherwise any kind of racing can become a drag.



This tangle of curves shows that bolt-on HP is real. The tests were run on a Stuska dyno 6/20/69 by the author. Starting with a 1500 cc 1967 engine, stock baseline curve 1 was run. In 2, the exhaust heat to the manifold was blocked off. 3 added an extractor-type 4-into-1 exhaust system with muffler. 4 is a Zenith 32 NDIX carb with 24 mm venturis (140 mains, 170 airs and 4K emulsion tubes) on a plenum-type manifold with a Bosch centrifugal-advance distributor. 5 added EMPI high-lift rocker arms, 6 shows the advantages of extra compression. Here we switched to heads which were flycut 0.100-inch. 7 shows the effects of adding a prototype Holley Bug Spray carburetor, jetted extra rich to allow it to run on the plenum manifold. 8 changed heads again to a set with 40 mm intake valves. Had we run the air-flow tests on heads at that time, this could have been equalled with the stock 35.5 mm intake valves. In 9, we returned to the stock-size-valve heads, but ran without a muffler. 10 added a stinger to give HP from the best bolt-ons—77.5 HP. An isolated-tube manifold, production Holley carb and flow-bench developed heads, in conjunction with a power pulley, should make over 85 HP easily available. Dual-port heads—which can also be considered as a bolt-on, would push the output to near 100 HP.

Adding performance

how three basic efficiencies affect HP output

There are three basic efficiencies to consider when improving engine performance: breathing, or consuming maximum amounts of fuel/air mixture; extracting maximum energy from available fuel/air mixture; and reducing friction and pumping losses. There are important relationships between these volumetric, thermal, and mechanical efficiencies and they are not readily separable.

When thinking about breathing improvements, consider the engine as an inefficient air pump. Cause it to pump more mixture in and thrust additional exhaust out and you add horsepower. The simplest and least troublesome way to move more air through the pump is to make it bigger by boring and stroking. Other steps, usually more complicated, will include reducing inlet and exhaust-path restrictions. Everything cannot be changed to the optimum, but each of the following is usually improvable: air cleaners, carburetors, intake manifolds, intake and exhaust valves and ports, valve timing and lift, and the exhaust pipes, manifolds, and mufflers. As you improve the engine's breathing ability, it will be enabled to turn higher RPM's, pumping still more air and giving higher output.

Getting the most energy out of the fuel being consumed as the mixture moves through the engine is largely related to two factors: compression ratio, and combustion-chamber efficiency. Improve Volkswagen's combustion-chamber shape for better turbulence and you can employ higher compression ratios. In the VW this means reducing the deck clearance. Other simple shape changes induce better breathing by allowing the valves to function more efficiently. This is discussed in the airflow section of the cylinder-head chapter.

Higher compression ratios produce more power from a given amount of fuel, up to the point where detonation occurs. This point varies depending on the modifications which have been accomplished and the octane rating of the available fuels. Combustion efficiency is also aided by ensuring that a proper fuel/air mixture is supplied, and that appropriate spark plugs fire it at the ideal moment for peak power and minimum heat losses. Additional energy is gained from fuel by polishing the piston tops, combustion chambers, and the valve heads. Polishing reduces the heat loss into these parts and thereby ensures that more of the developed heat is available to push the piston.

The last item is often overlooked or forgotten in engine assembly because it is so easy to overlook friction and pumping losses which are created in turning our "pump"—and which reduce usable power availability. Improving the breathing reduces pumping losses by allowing the pump to turn more freely as it gulps the same amount of air. Getting more power from a given amount of fuel also helps because friction is reduced to a lesser percentage of the total power being produced. Actual reduction of friction, however, is difficult to accomplish. Stock bearing clearances are not far from the 0.0025 inch (rods and mains) which gives best power and reliability. Piston rings, combined with the piston, probably contribute the maximum friction found in the engine. The necessity for sealing the pistons is obvious, but research is constantly being accomplished to come up with new ring and piston designs to assist in reducing this friction.

Piston clearances can be increased, but there is a limit, as excessive clearance causes piston "rock" and undue wear of the rings and grooves as their edges are rounded and pounded off. Still another friction source is misaligned pistons and rods which steal power and generate unwanted heat. Careful assembly will reduce this item to a minimum value, of course. There are other friction sources, including the valve train, which cannot be minimized to any great extent. Balancing further assists in reducing energy losses. It assures a smooth flow of power to the crankshaft flange, rather than a dissipation of energy into shaking motions. Reversing the pistons so the offset is on the opposite side makes them slap something terrible, but Vee owners report 1% to 2% HP increase along with the increased noise.

Valve springs, if too "heavy" for the cam being used and the RPM range to be used, can also steal HP by causing excess friction at the cam, lifter and rockers.

Jim Sibley, owner of Jim's VW Service in Lynwood, Washington, is shown here winning a "points meet" at Spokane in August, 1970. He blew off an "E" Modified Production Chevrolet in this run. Car's best ET is 12.06 seconds with a top speed of 104.68 mph.

How much HP can you afford?

look at the total cost *before* you start building *or* spending

Modified VW engines will produce over 150HP, but you may not want one of those because their life is often measured in minutes. Minutes are more time than you need for drag runs lasting 12 seconds or less. That's 5 runs a minute—or 20 runs in 4 minutes . . . and 20 runs is not a bad or unusual life for an all-out VW racing engine. Engrave these facts permanently on your head bone before charging off to build an all-out racer out of momma's grocery-getter. Otherwise, begin with some other engine which started out with stock HP closer to that which provides the kind of performance you like—such as a Corvair, for instance. So long as the HP is kept below the 150 figure, a remarkable amount of life can be obtained, even though this is literally three times the output for which the VW engine was designed. When the HP is in the 100 to 125HP region, the life is extended still further. If you stay below 100HP, then you can probably expect engine life about the same as that of a stock engine. This assumes that careful attention is paid to keeping the engine adequately cooled and supplied with a sufficient quantity of filtered oil which is not at some out-of-sight temperature.

Engine life in a wildly modified VW engine is dramatically short. There is just no way to take a 50HP engine design and make it produce over 150HP on a reliable long-term basis. Some never make it past the dyno stand. Chances are that you will be asked to pay for the engine before it goes onto the dyno. Then—if it blows—the hot oily pieces are yours.

You may not even get your money's worth as you observe because some blow-ups aren't even spectacular . . . just CLUNK!!! That's all she wrote, Charlie. Send more money and we'll build you another'n. Maybe we can save the fuel pump and carburetors!

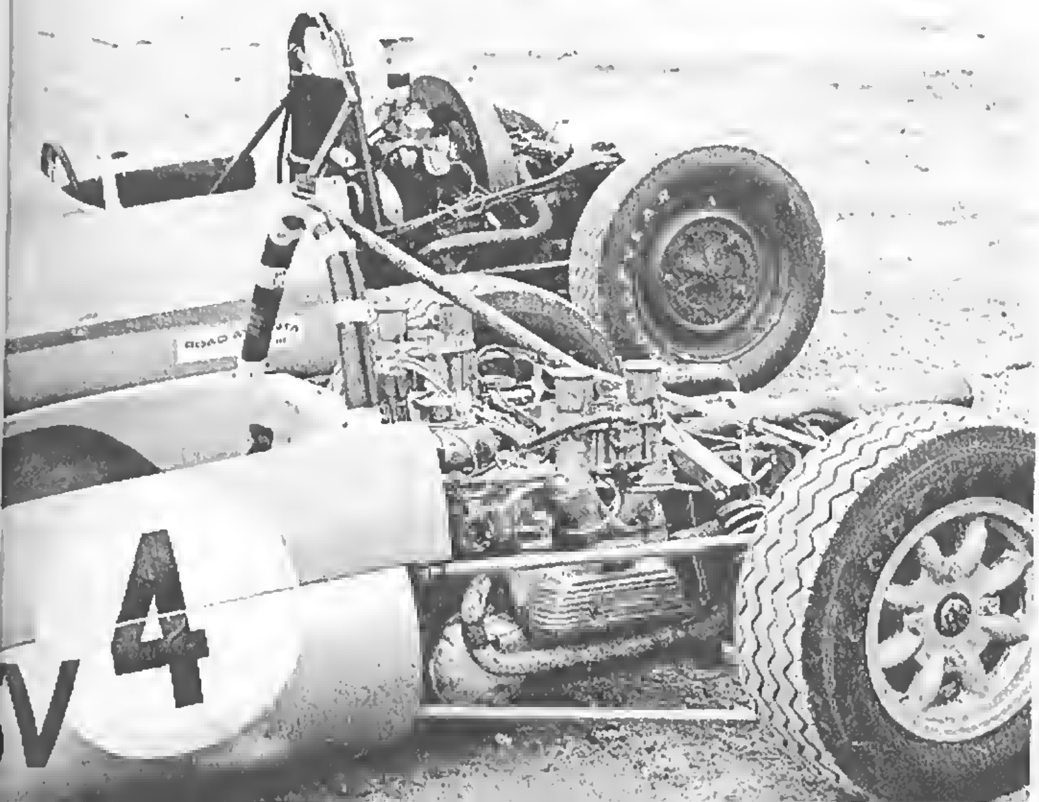
Pay first and test afterwards is standard in the racing business. It's not, contrary to what you might think, an unusual or cruel attitude on the part of the engine builder. He already knows what can happen—and you must be aware of the possibilities, especially if you are buying a high-horsepower VW. Furthermore—if you are a "hammer mechanic" or one who just refuses to read and believe what is required to make an engine stay together—then the VW is definitely not your "cup of tea." An infinite amount of painstaking care is required to assemble one of these little watchwinders and don't you ever forget it. Leave the beer guzzling to the onlookers—you'll need every brain cell that you can have working to make sure that you don't leave something out or overlook some fine point during the assembly. In fact, you may even want to work alone—or with not more than one person—because extra people only serve to provide distractions which could be expensive at best.

If you think that these statements are "against" the VW, you are wrong! I just want to be sure that you understand that the VW, like any other engine, has an enormous appetite for rectangular dollar bills, five-dollar bills, twenties, hundreds—you name it. Unless you are in a financial position to feed that kind of an appetite—stick with a milder form of hotrodding—or switch to a different engine which starts out on a heftier foundation with more cubic inches. It's fun to see 'em go—but be ready to pay for it when she blows—or else be content to spend the rest of your life as a spectator. Think about the costs of racing before you start if you want to stay out of hock and keep your own and your family's finances and relations in good shape. Racing offers an amazing amount of interesting fun and excitement, but an all-out racing effort is expensive in terms of the time and money investment which it requires. It's often been said that racing is a rich-man's sport.

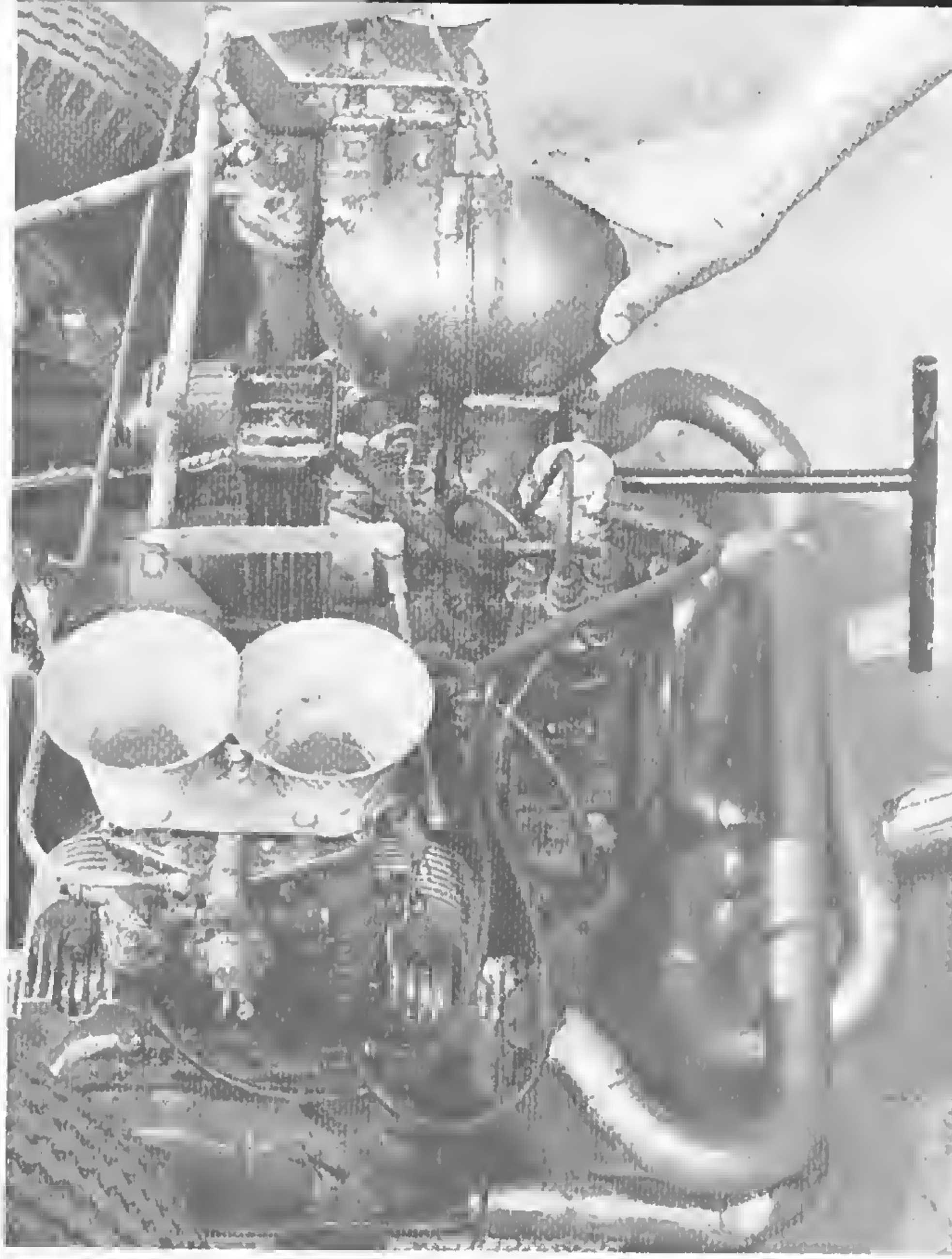
The facts and psychology are so well known that, in racing all parts or construction are either C.O.D. or C.I.F. (cash-in-fist) as Don Blair puts it—so don't get the mistaken idea that flashing a credit card will get you to first base with the hard-headed speed merchants you'll want to do business with.

A tube-frame dragster might cost you less to run than a sedan but

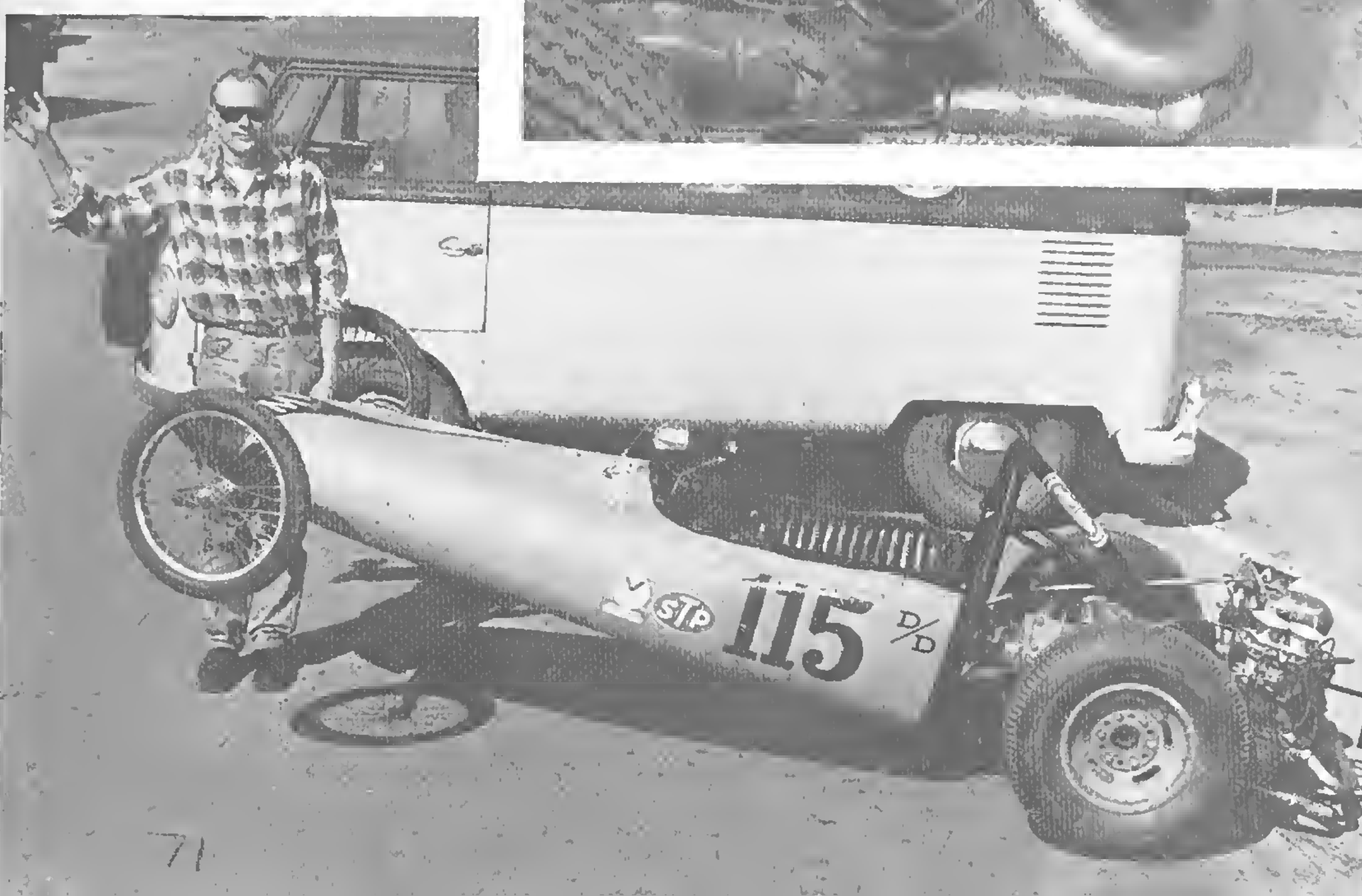
Super Vee 4 in foreground and Formula Vee 40 in back run out of Race/Chek's shop in Pompano Beach, Florida. Both are Beach machines.



there might not be any competition—at least at first. Without competition, running for fun might not offer you the satisfaction of wheel-to-wheel combat. By knowing and planning on the costs ahead of time you may be able to determine how best to achieve your own personal goals. A street machine can be wonderfully satisfying and will usually cost less in the long run than an all-out



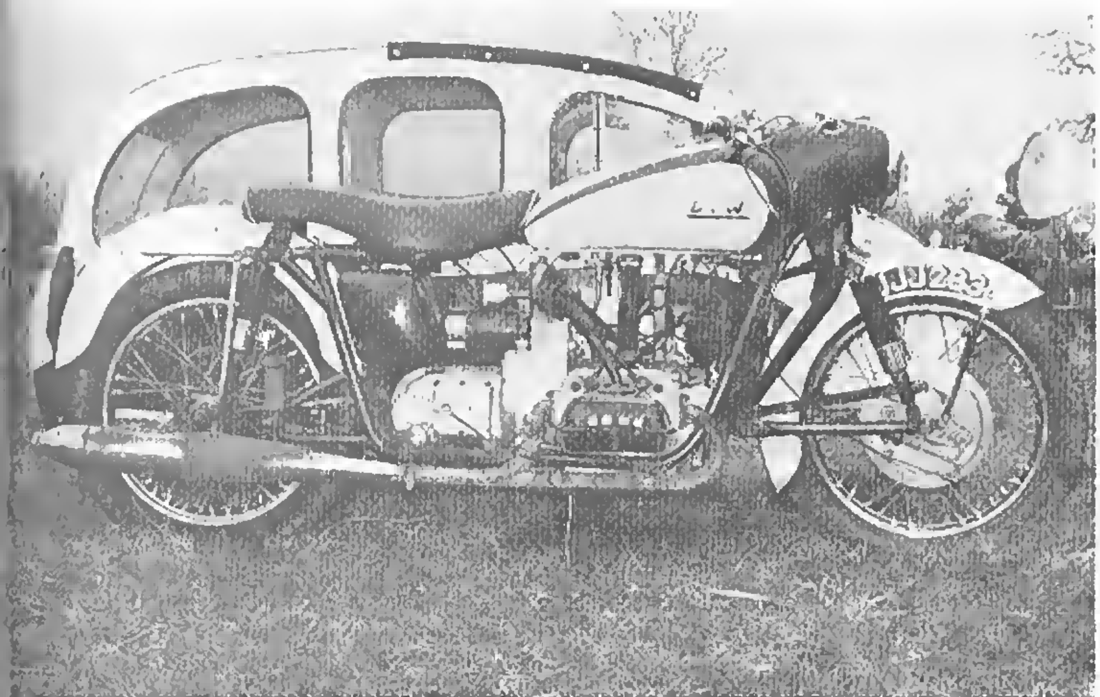
"Little but quick" is a 490-pound "D" class VW dragster which saw 123 mph 11.16 sec. E.T. action at Kent Pacific, Puyallup Valley and Arlington Raceways and the Winter Nationals during 1966 and 1967. Gene Berg based the power plant on a 40 HP 1959 transporter case equipped with 74 mm Okrasa crank and heads and Solex Porsche carbs on his own manifolds. Forged pistons in 90.35 mm Corvair barrels gave 1898 cc displacement. Body was unusual thin fiberglas shell filled with polyurethane foam. Exhaust system, one of the very first 4-into-1 types, was made into the first competition-tuned VW exhaust (29 inches to collector) with a slow taper megaphone. This change alone added 8 HP at 6,000 RPM. Engine also had 1.4 Berg rockers and full-flow filtered oiling system. Photos by Alex Walordy.



drag sedan. Don't be like so many would-be racers who self-hypnotize themselves into ignoring the monetary realities, preferring to think about that tomorrow. Some of the costs for typical failures may help to give perspective to your view: engine—$1,000; VW transaxle $200; Porsche transaxle—$300 to $500. To stay on top in the heat of competition requires the latest and best in racing slicks, which will usually cost in the $120 to $150 a pair region—plus mounting, truing and balancing. It all adds UP!

What Are You Willing To Trade?

Reading this book is going to give you all sorts of ideas about how to improve the handling and performance of your VW. But, before you begin to spend time and money—STOP! Consider both the pros and cons of such changes, especially if you are modifying the family's transportation. Can you *afford* to swap stock characteristics for the ones you *think* you need? For everything you get you must trade something in exchange . . . in addition to mere money!



Two VW-engined motorcycles by British builders. Top: Brian James' adaptation which uses a Douglas Dragonfly frame. Bottom: Alan Daff used a Norton "featherbed" frame and front fork. Both solved the transmission problem with a Douglas gearbox—something few U. S. crotch-karters have ever seen. Photos by C. Peckham originally appeared in Motor Cycle in December of 1968.

These statements do not apply to careful tuning to get the last ounce of performance from the stock design. Nor do they apply to increasing the displacement by boring and stroking, an almost trouble free—*but expensive*—modification. Nearly all of the other changes couple disadvantages with their improvements. To make you fully aware of the things you can lose, I have carefully discussed the disadvantages of certain modifications. You'll see these mentioned, right along with the good points, throughout this book.

Briefly, added HP and handling are not always advantageous if you have to sacrifice too many desirable or required characteristics. For example, Grand Prix cars have such highly developed engines that five and even six-speed gearboxes are needed to get good performance from the very narrow speed range in which the engines produce acceptable power. Were you to set out to extract the absolute maximum performance from your VW, this is exactly the type of situation which you could create. Special drag-race and auto-cross cars which are VW-based are usually towed or trailered and cannot be used for transportation, even with considerable detuning. Be careful that you keep your modifications within the limits of the use expected of the car.

A special note of caution for stick-auto and automatic-transmission owners. Be doubly careful what you do to your VW engine. It is absolutely essential to keep low-speed torque with the automatic transmission. Failure to observe this caution could cause you to end up with a literally undrivable horrible-example-type car. The manual gearbox and clutch combination overcomes or masks many of the problems associated with horsepower increases, but the automatic transmission will not cover up poor choices of engine characteristics created by poorly selected modifications, especially overcarburetion and a cam which is "too wild."

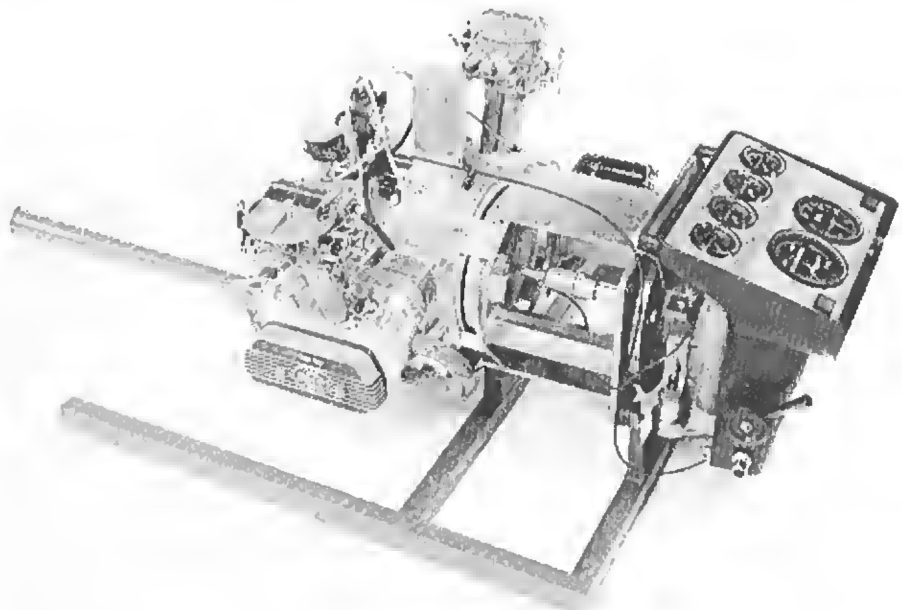
The same things can be said about handling modifications; consider the pros and the cons before spending time and money. You will often find that the more conservative, less-expensive modification provides the most usable driving fun!

HP ratings — real, or imaginary?

As part of the understanding of horsepower ratings, consider the fact that the Germans rate the 1285 cc engine (called the 1300) at 40 brake horsepower, while the United States says that it has 50 SAE brake horsepower. Actual tests show that the 1300 engine puts out close to 40 HP—unless you use "finagle" factors. Similarly, the 1493 cc or 1500 engine is German-rated at 44 bhp and we say that it has 53 SAE bhp.

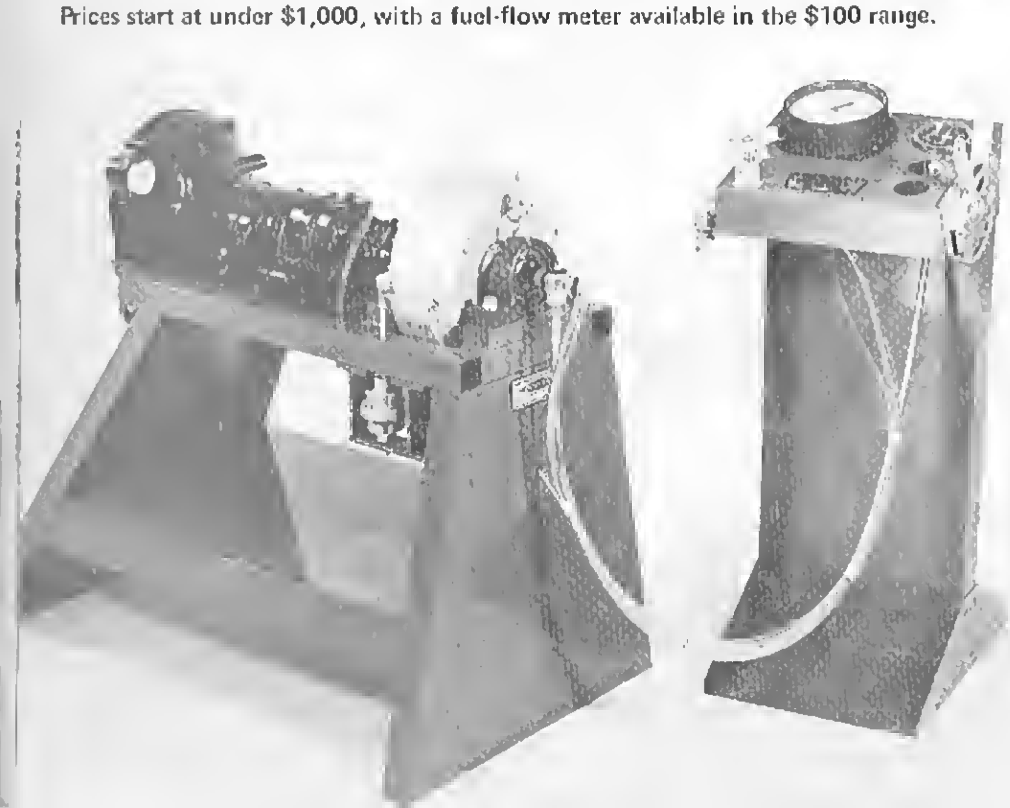
Factory ratings, with few notable exceptions, are obtained from custom handmade engines which have been carefully "blueprinted" from selected parts. Run-of-the-mill or standard-production engines assembled with random (non-selected) parts typically provide 15 to 25% less horsepower than the advertised ratings. This is because the Society of Automotive Engineers allows horsepower ratings which are obtained by skullduggery. The ignition can be set for the best power output at each RPM, there is no requirement that accessories be run—so fans, water pumps, electrical equipment and mufflers are left off. With this kind of a "tailwind," horsepower *sometimes* climbs to the advertised figures.

As of the 1971 model year, some sense began to appear as General Motors led the way with "as-installed HP" ratings which took into account the horsepower which the user might expect to get from the engine when it was burdened down with all of the power-robbing accessories. But, even this move was not without some selfish interest. It was done because of the rising insurance rates which were being applied to cars with horsepower ratings in excess of those which the insurance companies felt were required for the normal driver. I wonder how the insurance companies would factor some of the 100 to 150 HP VW's that are running on the street today.



Go-Power Dynamometer DA-300 with S-100 Porsche/VW adapter kit will handle up to 600 HP, sells for $2,045, complete. Air-flow and fuel-flow metering devices are also offered by the same firm.

Harvey Stuska's 175 HP water-brake dynamometer is an important item in the VW hot-rodder's tuning closet. Pressure gage and tachometer are isolated on separate stand mounting for freedom from engine vibration which can affect torque and RPM readings. Prices start at under $1,000, with a fuel-flow meter available in the $100 range.



In all of the dynamometer test figures and charts, I have shown the actual horsepower as read from the dyno torque arm or "beam reading." *Finagle or fudge factors have been eliminated.* Where a curve has been obtained from previously published data, the sources have been noted and the horsepower figures have been derated by the factor which is typically used to "enhance" horsepower. I want to be fair to those who have made the test data available, and—by the same token—I don't want to mislead you, the reader, even if you are an expert. The reasons which are given for using these factors range all over the map. One manufacturer claims that his customers don't want to be reminded that their "50 horse" engines don't really produce the factory-claimed 50 HP.

"Funny factors" enhance horsepower improvements out of proportion to their true benefits. Example: blocking the exhaust heat riser on the stock engine produced a 2.3 HP increase at 4500 RPM with no other changes, but with a commonly used factor or multiplier of 1.3—getting rid of exhaust heat to the manifold increased the engine's output by 2.9 HP, which certainly looks more significant.

Similarly, adding an extractor header and muffler combination either adds 3.3 HP or 4.0 HP, depending on how optimistically you want to look at it. Realistic HP increase is 7.2% over stock output of 46 HP. The optimist says, "This change gives an 8% improvement over the advertised 50 HP output."

Take your pick—but understand what you are picking. I have tried to show you what you can really expect. If you want to multiply the figures by 1.3 or another funny factor, be like the ostrich and fool yourself. So, that's why my horsepower figures and charts look so "low" when compared to brochure, sales sheet, or magazine-article horsepower figures, which are forever more impressive. Did I use a bunch of "puny" engines for my tests? Hardly!

Two comments of note. First, Jim Herlinger, West Coast Distributor for Lynx Vee and Super Vee, is a mechanical engineer who got a lot of his racing experience in Ford's High-Performance Group. He says, "Dynos vary from unit to unit—even when they are the same make and type—and require careful calibration to insure that they are reading accurately. However, you should never forget that the real reason for using a dyno is as a comparative device for checking on whether you are gaining or losing in the fight to get more HP. Correction factors for any dyno should not exceed 8%, even for the most extreme temperature and humidity conditions. My own typically requires about 4% as a correction factor."

Bob Wendland of ACE in Livonia, Michigan says that, "For comparison, our dyno data is corrected to 100°F and 29.42 inches of mercury. Correction factors typically run 1.06—just 6% over what we read off the shaft—or 1/5 the correction typically added on at Southern California VW speed emporiums."

Acknowledgements

All books of this type finally go to press as a result of the knowledge and help supplied by a lot of people. I want to recognize all of the men and firms who helped to make this book possible, but in so doing, I am certain to overlook some. To all of you who helped, thank you!

I'll start by thanking Art Stang, of Stang's Foreign Car Service, who has been encouraging me to write this book since 1964—five years before I started. Ray Longanecker, Dolf van Kesteren, Dean Lyon and Elliott Young are other San Francisco peninsulans who helped with ideas and suggestions to make the book more informative. Joe and Darrell Vittone of EMPI assisted with details of what they've found helpful in many years of beetle-rodding. Don Baker of VW Speed & Sport and Jim Herlinger provided especially helpful data as a result of their long association with Vees. Jeff Quick and Bob Wendland of ACE held nothing back in providing information on their Super Vee tests. Hal Klieves and Charles Anselmi of Race/Chek came through with a lot of good data, too.

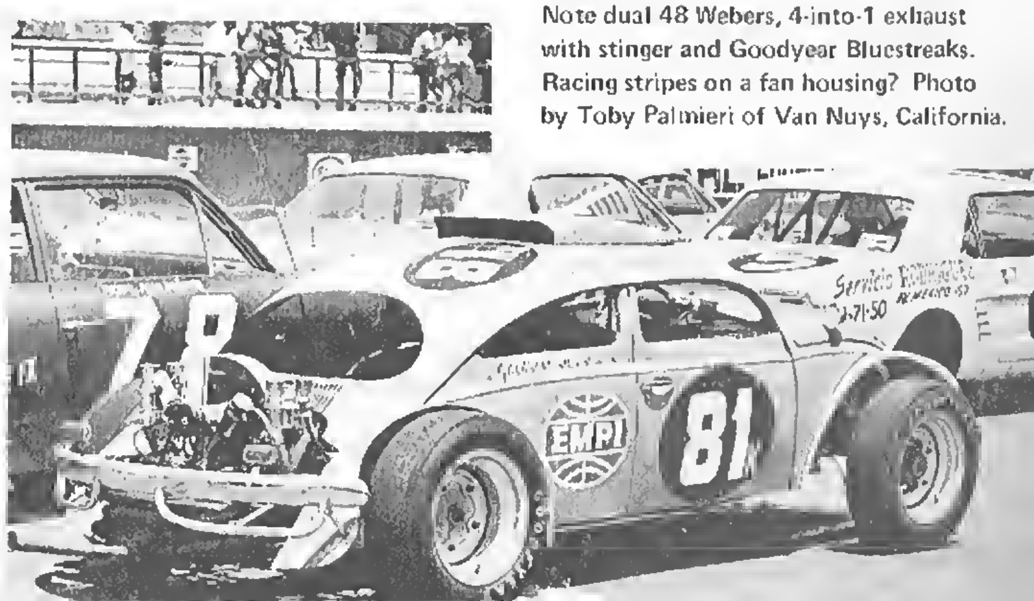
Josef Hoppen, Chet Bahn and Herb Williamson, of VW of America, provided a lot of the photos and background information which you'll see through the book. And Ray Litz is another expert who put up with my never-ending questions about how to get VW's to stay together. Tony Vierra of Bug-Formance read prepublication copy and urged me on.

Racer Brown gave big assists at various times. You'll see that Kay Sissell's advice to run air-flow tests on cylinder heads before publishing was extremely valuable. Ted Trevor helped by a critical scrutiny of the copy with lots of good suggestions about making it better. Paul Lamar's contribution to the handling and stability section may keep you from going on your head . . . if you heed what he says.

Gene Berg has constantly and consistently helped me with this project since May of 1969 when I first met him. Because of him, the book is 1,000% or more better than it could have been without his memory about what you need to know to make the VW run and last. Special thanks are due Gene because ever since I told him about my plans to write the book, he has made himself available to assist and run tests, regardless of the time of day or the press of his growing VW performance-parts business.

After acknowledging their help, let me hasten to point out that not one of these men would agree with everything I've said in this book. Even so, their assistance has been essential. This book on hotrodding the VW is not as complete as I'd like it to be and some of the points are not covered in as much detail as I would have hoped. Maybe we can change all that in a revision . . . someday.

In Mexico they race *modified* sedans. Vent-thing on top is entry hatch as doors don't work anymore. Roof lettering says "Inch Pincher" and side sign proclaims that the owner is an EMPI customer. Note dual 48 Webers, 4-into-1 exhaust with stinger and Goodyear Bluestreaks. Racing stripes on a fan housing? Photo by Toby Palmieri of Van Nuys, California.



Ignition

the stock system is better than you thought

If you follow my recommendations in this chapter, you will save the cost of this book several times over. You can save lots of money by using stock VW ignition parts because no horsepower can be gained by changing to a special ignition system. Your VW ignition system will provide maximum power in the most strenuous racing applications. Although there have been many different VW distributors, the chapter tells you which ones to consider for use in your engine . . . and why.

Spark-plug selection is also important for performance and types for high-performance, high-compression VW engines are discussed. The two bugaboos of high performance, detonation and pre-ignition, are covered in detail.

SPECIAL IGNITIONS

Glamorous transistor or capacitive-discharge ignition systems are interesting technical achievements, *but they are expensive.* Their real advantages include long point life, easier starting in cold or damp weather and increased spark-plug life. This latter feature is the real "plus" of the capacitive-discharge systems because these will fire plugs which are too worn out for peak performance with a stock ignition system. But, special ignition systems do not increase acceleration or top speed and they do not give more gasoline mileage than the stock ignition system in good condition. Peak ignition requirements, according to Champion engineers, are for maximum voltage at the plugs when the engine is being accelerated at low speeds under full throttle. Transistor and capacitive-discharge systems are equal to--but not better than--stock systems under these conditions. Buy a capacitive-discharge unit if you are choosing between these two types.

SEE THE SERVICE MANUAL, TOO

Material presented herein does not cover the entire picture, so you should also read the Engine Electrical Section of the VW Service Manual. It contains many important details which cannot be covered in this book. You should learn all about the ignition system to understand it completely.

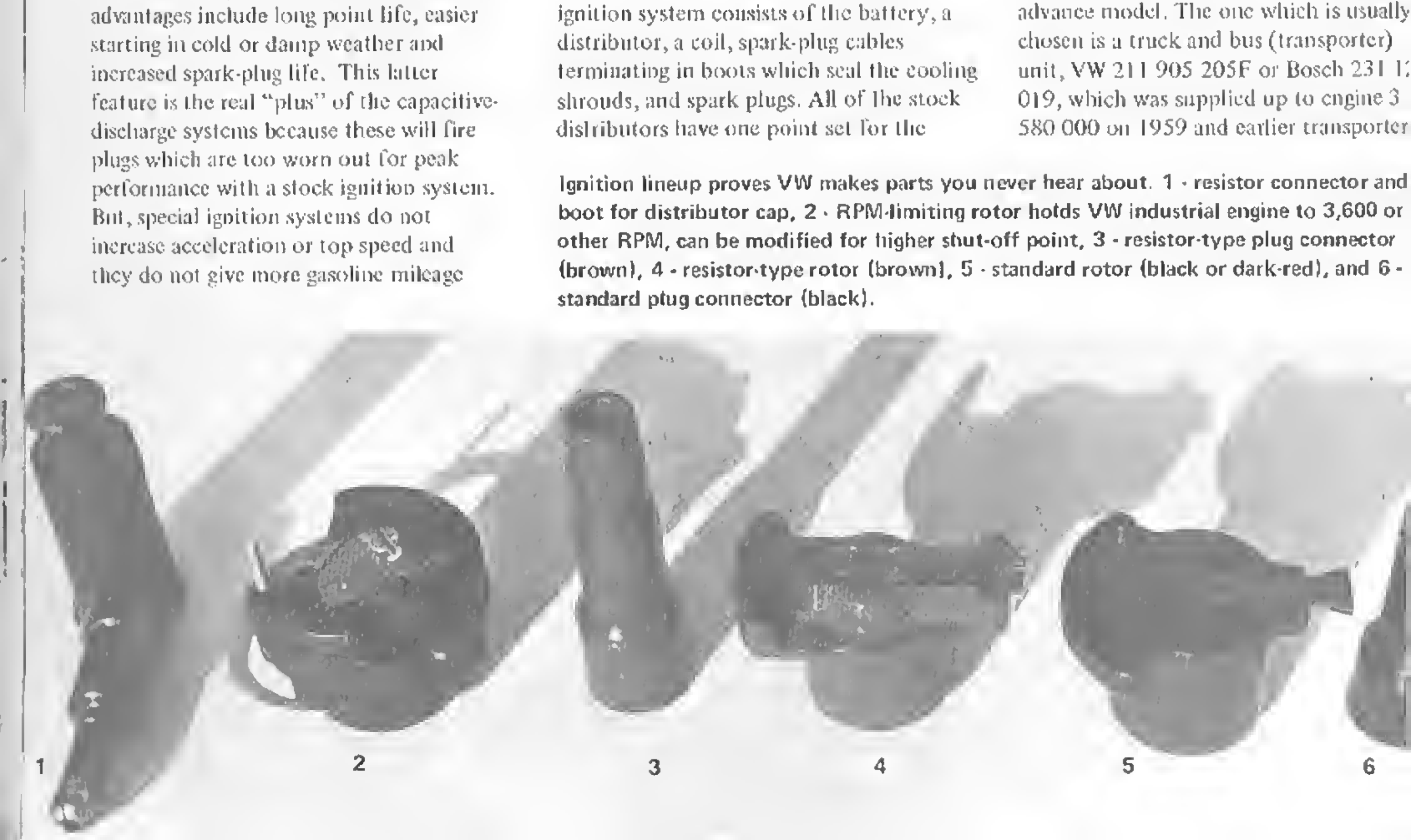
STOCK IGNITION SYSTEM

The stock ignition system consists of the battery, a distributor, a coil, spark-plug cables terminating in boots which seal the cooling shrouds, and spark plugs. All of the stock distributors have one point set for the ignition system. Fuel-injected engines have two extra point sets to sense engine RPM for the "computer."

There have been so many VW distributors that even a VW parts man has difficulty keeping track of what's been used on what car or engine. Some of these have been made by Volkswagen and others by Bosch. Basically, three types are identifiable by the manne in which the spark is advanced from its static setting of 10° or 7.5° BTDC or 0° (TDC). There is an all-mechanical or centrifugal-advance mechanism, a combination vacuum-and-centrifugal-advance mechanism, and an all-vacuum-advance mechanism. All of the distributors fall within these three types. Regardless of what you have read to the contrary, ther are no vacuum-retard VW distributors.

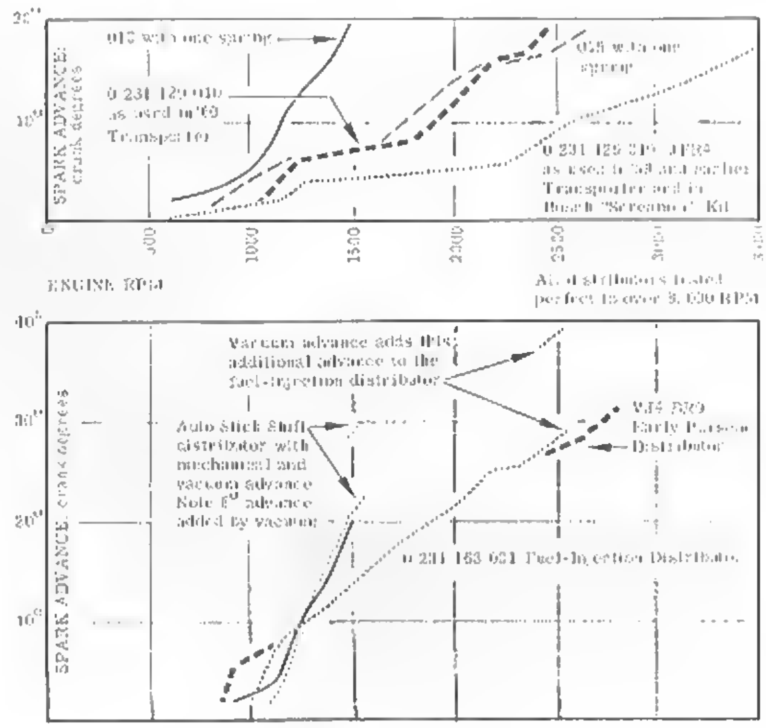
Ir general, it can be said that replacing the stock carburetor with any other type of carburetor(s) will usually eliminate the vacuum take-off provisions which are required for the all-vacuum-advance distrib utor. *Any attempt to operate without a advance mechanism will reduce the VW engine's horsepower output.* So, with a special carburetor which will not operate the vacuum-advance mechanism of the distributor at the correct rate, the distrib utor must be changed to a centrifugal-advance model. The one which is usually chosen is a truck and bus (transporter) unit, VW 211 905 205F or Bosch 231 12 019, which was supplied up to engine 3 580 000 on 1959 and earlier transporter

Ignition lineup proves VW makes parts you never hear about. 1 - resistor connector and boot for distributor cap, 2 - RPM-limiting rotor holds VW industrial engine to 3,600 or other RPM, can be modified for higher shut-off point, 3 - resistor-type plug connector (brown), 4 - resistor-type rotor (brown), 5 - standard rotor (black or dark-red), and 6 - standard plug connector (black).



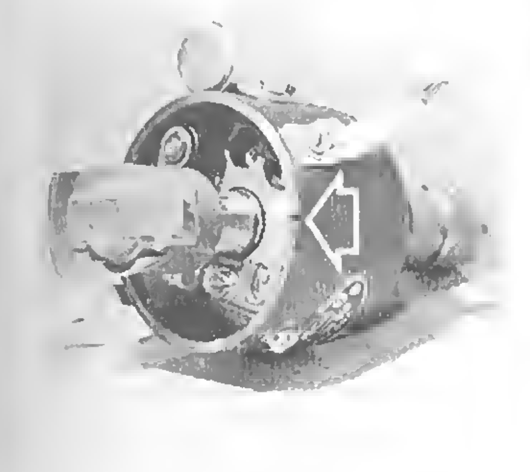
The '60 transporter unit can also be used, Bosch 231 129 010. It is also part of the Bosch "Screamer" kit which includes an 019 distributor painted metallic blue and the usual Bosch high-output blue coil with a chrome wrap-around cover. This 019 distributor has a total of 8.5° advance in the distributor which must be multiplied by two to get the crankshaft advance of 17°. The advance is "all in" by 3,500 RPM (engine speed) and the distributor tests miss-free to over 8,000 RPM engine speed. The 0 231 129 010 Bosch distributor used in 1960 transporters has a total of 10° advance in the distributor, or 20° at the crankshaft—all in at an engine speed of 2,500 RPM. It too, tests perfectly to engine speeds of over 8,000 RPM. For all-out acceleration, you'd be better off with the 010 because it has more advance and the advance is "all in" quicker than the 019. The advance can be gotten in even faster (20° crankshaft at 1,500 RPM engine speed) by taking off one of the two distributor springs. This distributor is the "hot setup" for VW's which will be raced, but the 019 is probably a better choice for an all-around street machine. Another distributor which is often recommended for the hotrodded VW engine is the Bosch 0 231 129 031. It has a total of 10° centrifugal advance in the distributor (20° crank). Its action is far too fast and makes idle setting impossible as it is already advancing during idle (advance all in by 1500 RPM engine).

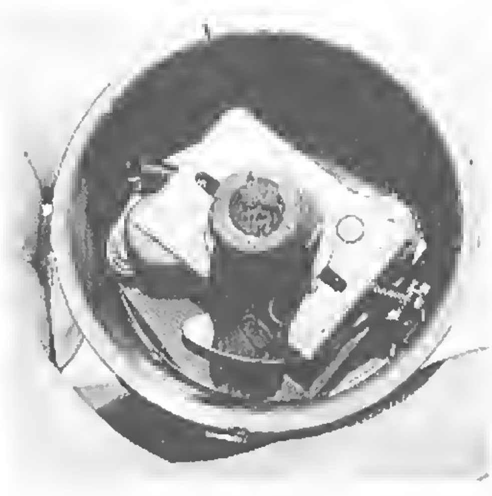
Centrifugal-advance Bosch distributors cost about $30. Purchase of any more elaborate distributor is not justifiable. In fact, it is hard to find a replacement distributor which will equal the quality of the Bosch unit. Take one apart and note the fit of the cam to the distributor shaft, the universal joint for alignment of the driving cog, the plastic sheet under the weights to allow smooth operation with little lubrication . . . and the way the cam is held in place with thrust washers and springs. The very high-quality construction makes these units an excellent buy.



Advance curves for popular VW distributors used in performance applications. All are mechanical-advance type. Recommended unit is the 019 with one spring or 010 with both springs.

Internal construction of Bosch distributor. With cap removed, line on rim shows where cylinder 1 fires (arrow). Point plate removed to show centrifugal-advance mechanism and wick for oil in center of cam (center photo). Removing springs allows cam to come off of shaft, showing long pin (arrow) and hole which limit total advance, weights which "fly out" under centrifugal force to advance cam against spring force. Formica sliding surface for weights is a quality feature.

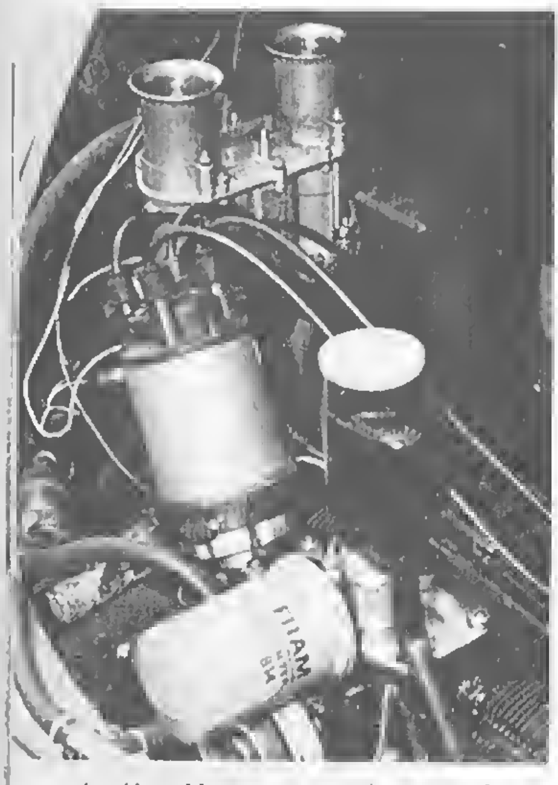




The distributor which is used on the automatic stick-shift VW's has both vacuum advance and centrifugal advance. This Bosch distributor 0 231 115 056 or VW 113 905 205 P has 11° centrifugal advance in the distributor (22° at the crankshaft) with an additional 4° vacuum advance (8° crankshaft) making a total of 30° advance available at the crankshaft. The fuel-injection distributor for the 311's has 15° centrifugal advance in the distributor with an additional 5° available by vacuum to make a total of 20° (40° crankshaft) advance.

The 1971 distributors have both vacuum and centrifugal advance. There is sufficient centrifugal advance in these distributors to allow using them with centered two-barrel carburetors which don't provide enough vacuum to operate the vacuum portion of the distributor. However, the distributor will have to be advanced to 7.5 or 10° BTDC, which will render the car unable to pass exhaust-emission tests.

A magneto ignition system is the perfect answer for super lightweight dragsters or circular-track racers which will be push started and therefore do not need a battery. But, if a battery must be carried to operate the starter stick with the stock VW ignition and use the money you save to buy some helpful item of speed or suspension equipment which will add to the performance of your VW. The only time that a special ignition will produce more horsepower than the stock VW coil and distributor (assuming that you are using the centrifugal type if that's required by the manifold you have chosen) is when the plugs are worn out or there is a problem with the stock system.



Joe Hunt Vertex magneto is seen on lots of drag-race VW's. Note degree plate on mag body to simplify setting ignition.

HOW TO IMPROVE THE STOCK VW IGNITION

A few of the stock VW ignition-system parts are nearly always exchanged for other stock or "high-performance" parts by owners who are literally "taken in" by ads for super spark plugs, extra-special spark plug wires, deluxe condensers, and long-life points. Save your money! If the distributor is not worn out and is the right kind for the carburetion system which you are using, there is little that you can do to make the VW ignition system work any better. Even the resistive-type cables, plug connectors and rotor won't cost you any horsepower if they are in good condition. The only reason to change them is if they are old and worn out. Even the stock coil works fine in high-performance applications. If yours has quit, the usual replacement is the Bosch "Blue" coil. It adds a colorful note to the engine, dressing up the black fan housing—but it won't add any horsepower, either.

The 1960-1966 VW spark plug and coil wires (high-tension) are of the resistive noise-suppressor kind which reduces radio interference. Cut one apart and you will find that there is no wire inside of the insulation—just a piece of graphited string. The plug connectors may also have a resistor built in. The only not of caution here is that you must be caref when installing and removing this type of wire because any sharp bend or yank will break the connector inside of the insulation and you won't be able to tell that this has happened unless you use an ohmmeter to measure the total resistance of the wire. As a good practice, you should replace the plug wires every two years or so—and more often in smog-ridden areas because smog really wrecks insulation. 1967 and later plug wires have stranded-metal conductors.

NOTE: VW's with 6-volt ignition systems have real troubles with plug life. When switched over to a C-D system or to 12 volts, the plug life gets back to a normal expectancy.

SPARK PLUGS

Spark plug life is such a problem in hotrodded VW engines that even stockers can seldom get VW's recom mended 12,000-mile plug life, even with cleaning at 6,000 miles. The problem is complicated when you modify the engine for more horsepower and then use the engine in varying ways—such as freeway driving, occasional drag races and the usual trips to the grocery store.

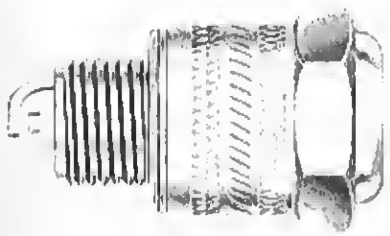
Plug life and consequently, replacement expense, can be enough of a problem to make buying a capacitive-discharge ignition system ver worthwhile. Some Porsche 911's, for instance, are factory-equipped with capacitive-discharge ignition systems to overcome their short plug life.

According to an article in CAR LIFE Magazine, July 196 the capacitive-discharge system increases usable spark plug life two to five times. Such systems greatly reduce the ills whic may result from inadequate ignition whe the conventional system nears tuneup time.

Stock-heat-range plugs recommended in the service manual may be replaced wi *slightly colder* ones when you modify th engine. But the cold plugs required for

best performance in all-out racing will not work for normal street/highway driving. They will make the engine spit back excessively, make gasoline mileage terrible, and the plugs will wear out or load up in a hurry, requiring frequent cleaning and/or replacement. A too-hot plug will last only a few miles and can cause destructive pre-ignition.

A near-perfect plug specifically engineered for the VW is the CHAMPION UL-82Y. It has a projected core-nose which acts as a "warm" plug at low speed and cools off to act as a "cold" plug as RPM's are increased. It also has an auxiliary gap which increases plug life between replacement or regapping because it changes the spark-voltage characteristic. When the spark has jumped the auxiliary gap it has sufficient voltage so that the electrode path will be used, rather than leaking away ineffectually across fouling deposits which may have built up on the porcelain and shell. The L-87Y is a slightly warmer projected core-nose plug without the auxiliary gap. The Bosch W145T also works well in the VW engine.



Champion extended core-nose construction could be called a variable-heat-range plug (see text).

Serious VW enthusiasts run a projected core-nose plug around town and switch to a colder plug for dragging. There's just too wide a heat-range requirement for any one plug to do the entire job in a hotrodded engine, although the projected core-nose ones come close.

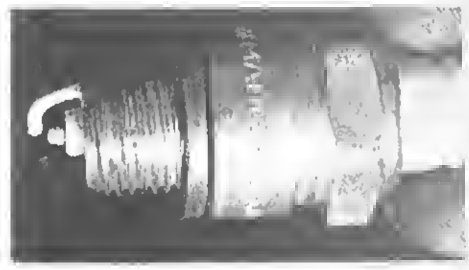
R. J. Gail, Champion Spark Plug's Racing Coordinator says, "The projected nose core plug benefits from the cooling effect of the incoming charge at high engine speeds. This 'charge cooling' on the projected firing end provides greater preignition protection at high speed and makes it possible to increase the insulator length on a given design, thereby improving the spark-plug-temperature characteristics. In many racing applications, with critical spark-advance settings, the possibility of core nose fracture from detonation would be more likely with projected core nose plugs than with regular types."

Engines with C-D ignition systems can perform o.k. with plugs which are one to two heat ranges colder than stock, providing performance similar to that which you'd get with new projected core nose plugs. If you are running a rev-limiting model such as Crown's Speed-A-Tron or the ARE unit, using colder plugs is necessary to keep "glo-plugging" from cancelling out the speed-limiting effects.

The stock plug gap of 0.028 inch is fine for a modified engine. The reach or thread length of the VW plug should be ½ inch, measured from the underside of the washer to the tip of the threads. It is very important to check the plug-thread length when you have the cylinder heads off of the engine because exposed threads on the spark plug—or in the head itself—get red hot and cause destructive detonation.

Spark plug should not extend into combustion chamber as this one does. Plug needs thicker washer so end will be flush with chamber when plug is torqued.

When substituting a plug with a longer reach, as you might have to do if plugs of the correct heat range were not available in the required reach, a thicker plug washer must be used. *Do not use multiple washers of the crimped-copper or crimped-aluminum type* as they will not conduct the heat out of the plug correctly. Champion offers standard 0.060, 0.080 and 0.100-inch-thick washers as standard items. Or, you may find that some of the copper oil-drain-plug washers sold for U.S. cars may work for this application.



Thick washers from Champion space the plug so that no threads will be exposed in the chamber.

When replacing spark plug and coil cables, consider using the new MSW Magnetic Suppression Wire as offered by Silver Beauty and other manufacturers. It allows full voltage to be delivered to the plugs but retains radio-interference suppression.

DISTRIBUTOR ADVANCE CURVES

Greatly increased advance in the lower-RPM range can usually be used in cars which will be primarily engaged in acceleration contests (drags). This is because the engine passes through the low RPM range very quickly, or is seldom operated there at all. Also, long-overlap cams pump part of the fuel charge back into the manifolds at low speeds, even at full throttle, reducing charge density and allowing more advance to be used. Thus, mechanical advance-curve changes can provide startling full-throttle-acceleration improvement. A total centrifugal advance of 16 to 20 crankshaft degrees should be "all in" by 3,000 RPM or even sooner for best performance. The accompanying distributor curves show which units can be used to get these quick-advance characteristics.

When the distributor advance-curve is changed, the initial setting can be increased by the number of crankshaft degrees the total advance was reduced—at least for a trial setting. Example: 28° original engine (crank degrees) advance reduced to 18°

is a 10° reduction. If original setting was 0° (TDC) add 10° to 0° for an initial trial at 10° BTDC. Experiment with the initial setting to determine the optimum position just short of detonation. Make your checks with the muffler installed so you can listen to the engine. Retard the spark several degrees when changing to a free-flowing or open exhaust system. What you are trying to do is to get maximum power by establishing the ignition-advance curve to keep the engine just short of detonation right through the RPM range when operating at full-throttle.

If you are using a used distributor, check that the shaft cannot be wiggled sideways in the housing (radial play). Also make sure that the point plate keeps the point rubbing block squarely with the cam. If you are using a vacuum-advance distributor, be sure that the points stay square with the cam as the advance mechanism is operated. If the point plate wobbles, replace the distributor. VW's don't run well with more than 32 to 34 degrees total advance (crankshaft).

WARNING! Do not coat spark-plug threads with anti-seize compound because it acts as an insulator and prevents proper plug cooling. Make sure gasket is crimped so it does not fall off plug during installation. Use a plug socket with an internal plug holder to ease plug installation. Torque plugs to 17 to 18 lbs. ft. with a torque wrench. Make certain that all of the plug seats are tightly attached or your engine will overheat because the cooling-air blast will leak out of the spark plug openings in the shrouds.

1969 VW stock engine. Vacuum-advance distributor identified by large "can" (arrow).

DO NOT DYNO-SET IGNITION TIMING

Dyno-set ignition timing will always be too far advanced. Such settings cause detonation because the engine is not allowed to take advantage of combustion-chamber turbulence, and because spark-plug temperature is greatly increased by advancing the spark setting. Detonation results in either case and can also lead to pre-ignition in the worst cases. This all happens because the chassis-dyno operator sets the distributor for the best *flash* reading, and you drive off the rollers with the engine detonating merrily. Worse yet, you may not drive the car after setting the timing on the dyno. If you enter the car in competition the chances are very good that you will not hear the engine detonating because exhaust noise will mask the detonation. The dyno operator is not likely to pay you for a blown-up engine. It is essential that you understand what can happen to your engine. The air-cooled engine cannot tolerate excessive spark advance because there are already enough problems involved in keeping it cool.

While it is possible to cheat a little on the factory settings by advancing a few more degrees beyond the shop-manual recommendations, detonation must be listened for and the spark retarded if it occurs. If you hear detonation and the engine is not being run with close to 32° total advance (crankshaft degrees), try increasing the size of the main jet. Or, look for exposed plug threads or a sharp edge on a valve or somewhere else in the combustion chamber. Excessive carbon build-up can also be the culprit.

Barney Navarro, in a 1963 Popular Hotrodding article, made the following observations. "Among the many things that affect the spark-advance requirements of an engine, we find engine temperature and air temperature. The hotter the fuel charge before ignition, the faster it burns, therefore requiring less spark advance. The speed of any chemical reaction is doubled by a temperature increase of 18° Fahrenheit, so it is easy to see that distributors should be fitted with temperature-compensating devices, especially those of air-cooled engines. The average modern overhead-valve engine can utilize from 5 to 8 degrees more advance when it is cold than when it reaches operating temperature."

Navarro's comments tell us why we ca get away with cranking up the advance for quick blasts on the dyno or a fast trip down the quarter mile—but destroy the engine by trying to use the over-advanced distributor setting for everyday driving.

DETONATION AND PRE-IGNITION

Detonation or "ping" is a sharp knock which make your engine ring or sing as if someone had hit it with a hammer. Skip Mason of Champion Plugs says, "It is like hitting the pistons, valves, spark plugs and other engine parts with a hammer." There is usually no problem in identifying detonation because you can hear it—unless you are running the engine with open exhaust. *Detonation is spontaneous combustion of fuel in the chamber instead of the desired controlled "slow" and even burning.* Perhaps the most common cause of detonation is overadvanced ignition timing, but there are othe causes which should not be overlooked. I can also be caused by full-throttle acceler ation with too-high a compression ratio; high operating temperatures, too-hot spark plugs, and lean mixtures can all be contributing factors to cause destructive detonation. Detonation results include hammered-out bearings, broken rods and crankshafts, sharp-edged holes in piston crowns, and broken ground electrodes on spark plugs. It also breaks ring lands and cracks piston skirts.

Pre-ignition is ignition of the fuel while the compression stroke is occurring, but much earlier than intended It can be caused by glowing plug, sharp valve edges, overhanging gaskets. Pre-ignition can be temporarily reduced by retarding the spark, but this creates excessive heat and detonation sets in due to this heat—as a result the fuel fires as it enters the chamber. Complete chaos and a destroyed engine inevitably result from pre-ignition.

COIL

Because the stock VW coil does not look very "racy," a lot of VW owners replace it with the Bosch Blue Coil for about \$10. That same \$10 would help to buy something helpful—such as a small-diameter crankshaft pulley, for instance. If you need new points, get new genuine Bosch points, which have a visible layer

of tungsten which can be filed once or twice before replacement—so long as the fiber rubbing block is not worn out.

VW DISTRIBUTOR CAMS

Don't be surprised when you run one of these distributors on a distributor machine and find that one of the cylinders fires 2^0 (distributor) retarded. Because these distributors were designed specifically for the VW-type engine, the No. 3 cylinder fires 4 crankshaft degrees later than the other cylinders to temperature-compensate it for its tendency to run hotter. It runs hotter because the stock oil cooler blocks the air to that cylinder. This is the reason why the service manuals make such a big point of insisting that you time the engine on No. 1 cylinder with the distributor in a specific position to fire No. 1 cylinder. It is also why you should install the spark plug cables correctly in the distributor cap exactly as they come from Wolfsburg. You cannot wire the distributor in just any position even though you use the correct firing order—regardless of your past experience with other cars.

VACUUM DIAPHRAGM FAILURES

Ray Longanecker has a troubleshooting clue for any VW or Bosch distributor equipped with a vacuum diaphragm—if you find severe point burning and arcing evidence at the rotor and cap, don't reassemble everything until you check the diaphragm. A failed diaphragm will allow gasoline fumes to leak in the distributor where they will burn, creating this condition. It's something you should always check out on a vacuum-advance distributor.

Tuning Stages Table

36 HP

BOLT-ON STAGE

Extractor exhaust system, block heat risers to intake manifold in warm weather or for competition.
Power pulley
2-barrel carburetor
Centrifugal-advance distributor
Big bores not recommended
Flycut only 0.020 to 0.040 inch as required for a good sealing surface for cylinders. Note that the rocker shafts mount in curved saddles. Use equal-thickness flexible shim stock at each saddle if shimming shaft to restore rocker geometry. Do not use washers to space shafts away from head. Instead of shimming the shafts, it is far better to shorten the pushrods as detailed on page 112 — but hold the tappet face against a wood block when driving in the insert at the rocker end of the pushrod/tappet assembly.
Competition valve job, new exhaust valves, EMPI replacement valve guides.

HOT-ROAD & ALL-OUT STAGES

Not recommended for 36 HP

WARNING - Do not exceed 7.7:1 compression ratio on the 36 HP engine.

40 HP

BOLT-ON STAGE

Extractor exhaust system, block heat risers to intake manifold in warm weather or for competition.
Power pulley
2-barrel carburetor
Centrifugal-advance distributor
Flycut up to 0.100 inch but do not exceed 9:1 compression.
Competition valve job, new exhaust valves

HOT-ROAD STAGE

Same as Bolt-On Stage, plus:
69 or 74 mm stroke crankshaft, either stock or SPG-roller-bearing type.
82 or 83 mm big-bore pistons/cylinders
Porting per details for single-port heads
Head flycutting must match the bore and stroke so that 9:1 c.r. not exceeded.
Mild camshaft with not more than 280^0 duration — but only if 2-bbl. carb used.
Insert cam bearings (Rimco)
Full-flow oil filter with auto-stick-shift oil pump.
Transporter-type clutch P/N 211 141 025D

ALL-OUT STAGE

The Hot-Road Stage is the maximum hotrod stage recommended for the 40 HP engine. For an All-Out Stage engine, it is preferable to use a 1300/1500/1600 engine as a base. However, dual-port heads with 1.1:1 rockers can be installed for added performance. This requires machining spigot counterbores in the heads to fit the stock or big-bore cylinders. Cooling shrouds must be modified to seal against the heads. Use single 2-bbl. carb or dual Solex, Holley or Weber carbs. A higher lift and longer duration cam can be used with the dual port heads.
Porsche 180 mm diaphragm clutch needed, modified as described for 1300/1500/1600.

NOTE: When flycutting 40 HP heads, the clearance between the cylinder fin and the first fin of the head must be carefully checked.

1300/1500/1600

BOLT-ON STAGE

Extractor exhaust system, block heat risers to intake manifold in warm weather or for competition.
Power pulley
2-barrel carburetor
Centrifugal-advance distributor
High-Lift rocker arms
Competition valve job, new exhaust valves
Flycut up to 0.100 inch, but do not exceed 9:1 c.r., taking into account the final bore and stroke to be used.
200 mm Luk-type diaphragm clutch, P/N 211 141 025B, or 180 mm Porsche diaphragm clutch with diaphragm edge carefully radiused and moly-lubricated, or Crown 200 mm diaphragm clutch.

HOT-ROAD STAGE

Same as Bolt-On Stage, plus:
88 mm big-bore pistons/cylinders
2-bbl. carb with single- or dual-port heads, or dual 2-bbl. carbs with dual-port heads, or electronic fuel injection if no more than 6,000 RPM needed.
Cam with 280^0 to 290^0 duration and 0.450 to 0.500-inch lift at the valves.
69 mm stock, counterweighted or SPG-roller crankshaft, or use longer stroke crank up to 82 mm stroke.
Full-flow oil filter with auto-stick-shift pump
Porting per details for single- or dual-port heads.

ALL-OUT STAGE

Same as Hot-Road Stage, plus:
40 mm intake valves, 35 mm exhaust valves
Longer duration and higher lift cam if this better fits the engine to the application.
Competition exhaust system with megaphone
External oil cooling if used for road racing
Crown 200 mm diaphragm clutch with competition-type pressure, or dual-disc clutch

Carburetion

a little may be better than a lot

Most VW engines you see are in beetles and these are equipped with one Solex single-throat downdraft carburetor. But, this is not the only stock carburetion set-up which you can find on VW's. Early European model fastbacks and squarebacks had one Solex single-throat sidedraft carb. Later fastbacks and squarebacks which were imported into the U.S. were equipped with two Solex single-throat downdraft carbs—one for each cylinder head.

Beetles, busses and transporters use the single-throat downdraft Solex 28PCI on 1100 and 1200 engines. This carb has a removable 20 mm or 21.5 mm venturi in 36HP and 21.5 mm in the 40HP engine. Late 1200's and 1200A's have the 28PICT or 28PICT-1 carb with 22.5 mm venturi. The "T" in the designation tells you that the venturi is fixed (non-removable). 1300's and 1500's got the 30PICT or 30PICT-1 jugs with a fixed 24 mm venturi. Did the factory change to fixed-venturi carbs to thwart your tuning efforts? No, as production levels increase, manufacturing engineers strive to eliminate parts and subassemblies. Parts left out of a carburetor—or anything else—help to reduce manufacturing costs. No U.S.-made car has a carburetor with removable or interchangeable venturis—for the same reason. The number prefixes (28, 30) refer to the throttle bore at the carburetor to manifold flange joint—not to the venturi size.

When the changeover to the fixed venturi carburetor was made, the factory also switched from a manual to an automatic choke. The distributor was changed to an all-vacuum-advance type at the same time, with a vacuum takeoff for the distributor built into the carburetor. The VW automatic choke is thermostatically controlled by a heater element connected to the ignition circuit and is also responsive to ambient temperature. A vacuum diaphragm is also connected to the choke so that it will automatically open on acceleration.

Carburetors mentioned previously are mounted in the center of the engine on a steel-tube manifold. Exhaust gasses are used to heat the manifold for quick warmups and smooth running in winter. For warmer climates and summer running, eliminating manifold exhaust heat will add HP.

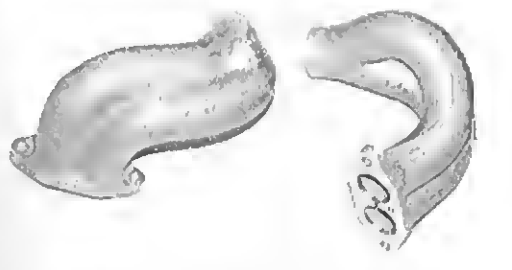
In addition to the hot-spot on the intake manifold, 1961 and later VW's have preheated carburetor air for a further improvement in engine performance on cold days and while the engine is cold. The same system assists in the reduction in exhaust emissions. The proportion of warm air to ambient-temperature air is determined by weighted vanes which admit more warmed air at low engine speeds . . . and close as engine speed increases. If a slower engine warm up can be tolerated, these vanes can be blocked to provide cooler inlet air to the carburetor. If the tubes from the exhaust heater are removed, the openings must be blocked so that the engine compartment is not filled with warm air.

The 28PCI carb used from 1954 through 1960 has a removable venturi. The 28PICT with cast-in venturi and automatic choke came on 1961 models. A shut-off jet for idle fuel was added to this carb for busses and transporters in 1963. The electromagnetic fuel cutoff jet for the idle fuel circuit effectively eliminates the engine running on after the key has been turned off. This same fuel shutoff became standard on beetle engines in 1966 when the carburetor was changed to a 30PICT-1 with a 2 mm larger venturi and a 2 mm larger throttle-body bore. The jet can be screwed into any of the 28PICT, 28PICT-1, 30PICT, and 30PICT-1 carburetors. All that's needed to make it work is one wire connected to the coil's positive terminal.

1968 VW's in the U.S. got an unusual-appearing squared-off carburetor to reduce emissions. The Solex 30 PICT-2 has a throttle-snul bing device to slow the throttle from being snapped closed (it takes about 3 seconds to return to idle from 3,000 RI with the car standing still). This device holds the throttle partially open when t engine is on the overrun with no pressu on the accelerator pedal. Thus, while t car is slowing down, the cylinders are ke filled with a combustible mixture which will completely burn, thereby drasticall reducing emissions by the simple exped of an annoying fast idle.

1500N and 1500A VW's were not imported into the U.S., except in rare instances. A center side-draft carburetor, the Solex 32 PHN or PHN-1, connects through an elbow to a air cleaner. The carburetor has a 23.5 venturi. Air-correction-jet access is through a small cover on the top. The main jet is in a holder on the left side o the carb. A power system is included. Dual-carb 1600 cc engines first appeare in U.S. Volkswagen dealerships in 196 ('67 model year), although 1500 and 1600 VW's had occasionally been impo by individual tourists since 1962. Thes are equipped with two single-throat downdraft Solex 32-PDSIT carburetors with removable 23 mm venturis (early models had removable 21.5 mm ventur

Pit area at VW Drag Races, Carlsbad, Calif., 1970.



1971-72 VW cast-aluminum manifold ends join single-tube to dual-port heads. Small balance passage between ports at head end should be filled in with Devcon F or heliarc when using these parts with a center-mounted Holley Bug Spray. See manifold on page 37.

A single air cleaner is ducted to feed both carbs. The carburetors are mounted on single-port heads. You cannot assume that a dual-carb VW 1500 or 1600 has dual-port heads because it does not! The 1966 versions of these carburetors did not have a power or high-speed enrichment system. A high-speed power circuit was added to the 1967 models. When these engines are equipped with 32PDSIT-2 and -3, -2 is the left carb and -3 is the right. Of course, there are VW squarebacks which have dual carbs on dual-port heads. These use the 32 PDSIT carbs on tiny one-into-two manifolds.

1971 Carburetion

1971 VW 1600's have a single 34 PICT 3 Solex one-barrel on a center tube manifold connected by hoses to castings at each cylinder head. The availability of these stock parts will allow using dual-port heads with less expense than was previously required when you had to buy a special carburetion system to use these good heads. The manifold castings are 113 129 705A (left) and 113 129 710D (right). A center piece which includes the carb mount and exhaust heat risers is 113 129 029S. Maybe the "S" stands for smog, which I wish we had less of. This center piece has a 32 mm (1.26 in.) horizontal tube which mounts the carburetor on a 34 mm (1.34 in.) downspout.

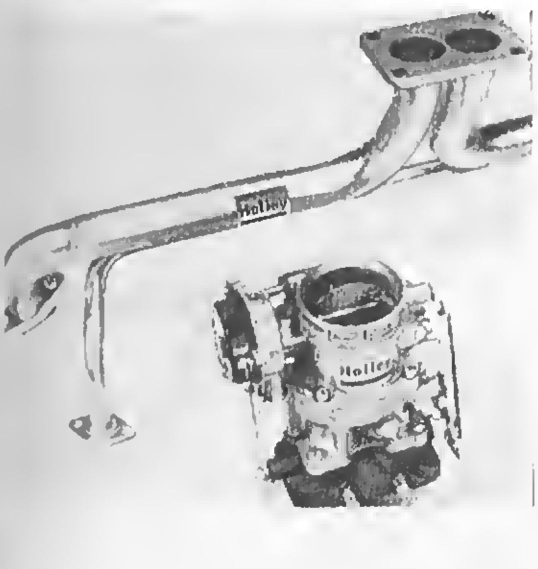
The 34 PICT 3 Solex has a 27mm venturi to pass the air required for the higher HP rating (60 SAE, 51 DIN). A built-in idle-carburetion circuit allows the throttle to be completely closed at idle. Starting the throttle from this completely closed condition reduces tip-in flat spots because the throttle is correctly situated in relation to the progression ports. The carburetor also gives more exact control of the vacuum for the distributor advance. A combination of vacuum and centrifugal advance is used to allow the engine to live with the *5° after TDC* initial setting needed to pass the California Cycle emission tests.

This carburetor provides more top-end performance, yet works within the confines of the smog requirements. However, the first owners of 71's reported a flat spot in the mid-range. This could be due to the plenum effect of the larger manifold cross-section, which accentuates problems with a carburetor which must be jetted lean to pass the emission tests.

Tuners who want more performance from a stock-appearing engine should consider using this new carburetor, but if they do, they should also make sure that the center down tube of their old manifold is made at least as large as the '71.

Installing a two-barrel carb—such as a Holley—is easily accomplished on the 71's. Just take out the stock center section with the one-barrel Solex and insert the center section of a 1-3/8" diameter isolated-tube manifold into the rubber connectors at each casting. You may have to add a brace so that the entire center section won't tilt when the throttle cable pulls on it. This simple modification—with the stock distributor timed to 7½° BTDC—will get rid of the flat spot and add several HP at the same time.

Edelbrock 1300/1500/1600 single-port manifold for Holley's Bug-Spray carburetor exemplifies quality workmanship throughout and has performance to match. Use with Bosch centrifugal-advance distributor.



BASICS OF CARBURETION

The carburetor is a mixing and metering device which automatically combines air and gasoline in the correct proportions for varying engine speeds and loads. Although it performs a complex job, the carburetor is a simple low-cost device.

The carburetor places a restriction (venturi) in the air-inlet path to measure air and create a reduced-pressure area. A discharge nozzle in this area connects to a fuel bowl vented to atmospheric pressure. Although the nozzle is located higher than the gasoline level in the bowl, any decrease in pressure at the nozzle causes fuel to flow through it. As air is sucked through the carb by piston strokes, fuel from the nozzle is added to the air stream in relation to the air velocity.

Compensating devices such as special jets, air bleeds and emulsion tubes, etc., are built into the carburetor. These devices actually improve fuel atomization because they mix air with the fuel ahead of the jet. Thus, fuel flowing into the venturi area is already partially mixed in an air/fuel emulsion so that it can be

more readily atomized by the fast-moving air stream. At all speeds above idle, air passing through the venturi determines the vacuum present at the nozzle (pressure drop) to draw fuel into the air stream. If air speed is too slow, atomization is not complete and fuel deposits on the manifold instead of continuing to the cylinders.

Careful venturi sizing insures that air velocity through the stock carb(s) will always be sufficient for adequate fuel/air mixing—even at the lowest speeds. The net results are smooth idling, good low-speed acceleration, a decent mid range and top-end performance that's hardly outstanding. This carefully designed setup reduces top-RPM HP because there is an excessive pressure drop across the venturi(s).

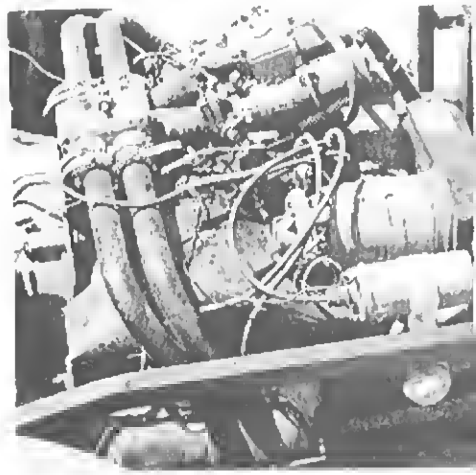
Experts who have researched the problem for years say that ideal *racing* carburetion should show a pressure drop not exceeding 1.0" of mercury (Hg) at full throttle under full load. What they are saying is that the pressure in the manifold should approach atmospheric pressure under those conditions. But—racing and transportation cars are totally different breeds of cats! The racing engine typically has a rough, lumpy idle, and it gives you miserable low-end torque coupled with poor engine flexibility—which means constant gear shifting to keep the engine in a usable speed range where the air velocity is adequate for good air/fuel mixing and consequent good distribution to the cylinders. If you have ever owned a high-performance sports car, you'll immediately recognize these symptoms—you must "row" the car with the gear shift lever in traffic—and rev the engine to get out of your own exhaust to move away from a stop.

Good low-end punch with an excellent mid-range and a better-than-average top speed is provided by a carburetor system giving a minimum pressure drop not greater than 3.0" Hg at WOT (wide-open throttle). Racing systems are set up to give 1.0" Hg at WOT. But, when you add carburetion capacity to get in this ball park you add more problems than performance. This is because adding carburetors of increasing venturi size decreases air velocity through the carburetors. When velocity falls below a "critical" value at which fuel and air cease to meter in the correct proportions, the engine is overcarbureted and produces little power at or near that RPM where the critical value is reached. Undesirable results include: poor low-speed torque, weak mid-range, and a powerful top end once RPM is increased to the point where air velocity will cause fuel and air to meter correctly. Remember—the larger the venturi, the greater the top-end capability—but with a resultant loss in low-end response. Engines with a lot of venturi area . . . especially small-displacement engines such as the VW . . . can be said to have a "soggy" bottom end.

Detroit solved the problem on big V-8's with the four-barrel carb which has both primary and secondary venturis—additional carburetion is available in variable fashion so that the engine is neither overcarbureted at low speeds, nor undercarbureted at the high end. The primaries provide for idling and mid-range—and two secondary venturis come in for top RPM.

There is no four-barrel designed to give good all-around performance on a VW engine. While you could probably make one work on an all-out racing engine, forget the four barrel unless you are a carburetion expert and love to tinker instead of winning races.

Adding carburetion capacity (more carburetors or larger venturi/s) causes flat spots at low speeds and reduces engine flexibility. You can't argue with the laws of physics—with the same engine speed and displacement, a large venturi area will slow down the mixture and detract from good vaporization. It may be almost impossible to get a smooth transition from idle to the mid-range. These problems should not bother a drag racer or road racer, but they can make a street machine extremely tough to live with for normal driving. A long-duration camshaft further complicates the situation by pumping back a part of the intake charge, further reducing the average air speed through the venturi.



Weber DCOE side-draft carb mounted onto fuel-injection manifolding. If venturis are kept in the 28 mm to 30 mm range, this will work well. Large venturis will kill low-end response and give low mileage that will make the gas stations think you are driving a Cadillac. Bob Waar photo.

A velocity stack on the stock Solex shou be at least as tall as the internal dimensi of the air cleaner to contain fuel stand-o spray, otherwise carb will run quite lean without cleaner.

Quickly open th throttles of any carburetor arrangement with large venturi area and the engine w misfire momentarily—or even die! Why Because manifold pressure rises almost t atmospheric, air velocity drops . . . and fuel deposits on the cylinder walls. The mixture, now mostly air, arrives at the cylinder too lean to support combustion Many auto enthusiasts have the idea tha quick throttle opening floods the engine with excess fuel, thereby causing the bo stumble or roughness. 'Tain't so!

IMPROVING STOCK CARBURETION

There are many reasons why you might want to improve your VW's stock carburetion. You may want to contend in "stock" classes at either drags or autocross races—or both. Or, you could want every last ounce of performance which you paid for in the stock VW engine. VW's stock carburetion systems are fine for economy and all-around uninspiring performance. The small-venturi carburetor(s) gives good low-speed torque, fine engine flexibility and restricted power output at high engine speeds. Simple changes to VW's well-engineered stock-carb system can provide enormous performance improvements, but you must keep in mind the fact that every "advantage" has an offsetting "disadvantage" when you are modifying an engine. If you make the mixture rich enough for best top-end performance, then mileage will suffer and you'll undoubtedly create "holes" in the performance curve. That is, your engine will probably not provide perfect operation all through its RPM range.

Careful tuning of the stock carb(s) will usually add HP, but it's hard to find these missing horses unless you have a mixture analyzer or a dynamometer . . . or both.

The first thing you should do—even if you never plan to race—is to remove the air cleaner (temporarily!) so that you can peer into the carb's air-inlet horn. Have someone else mash the throttle to the floor as you check with a flashlight to make sure that the throttle is fully open (not slightly angled) when the pedal is "floored." If it's not opening fully, figure out why and fix the problem. Any time you remove and replace the carburetor—check again to insure that you have a fully opening throttle. It is the easiest thing to overlook and the cause of a lot of lost races or poor times. Any honest racing mechanic will admit that he's been tripped up by a part-opening throttle at least once. It's happened to me several times.

Most of the problems related to failure to get full throttle are due to the design and location of the gas pedal. Dirt gets under both the front and back stops, so you may want to grind these off a bit. The older 1956-57 roller-type gas pedal is the best—or use the complete 1967 pedal assembly. The 1958 through 1966 assemblies are a problem because the arm from the pedal to the cable tends to bend so that the pedal goes sideways instead of down.

Now put the air cleaner back in place. Don't leave it off. This is the first temptation that you have to overcome in working on the VW. The time-honored mark of the performance-oriented owner may be an engine with no air cleaner, but you can't afford to copy all of the things which have been proved not to work. You must proceed in a heads-up intelligent fashion to keep everything working for you—not against you. The VW engine is so small that it needs all the help you can give. Leaving the air cleaner off makes the VW run lean at high RPM's because the cleaner contains the fuel "fog" which stands above the carburetor inlet at high RPM. Air cleaners also protect against fires caused by starting "belch-backs"—reduce intake noise—and reduce engine wear. Special air-cleaner recommendations and arrangements for VW's are fully detailed in one of our other books, "How to Prepare Dune Buggies and VW Sedans for Off-Road Use."

Before leaving the subject of air cleaners, let me remind you to look at the way the VW cleaner is designed before you invest in some flat-topped short cleaner because it looks good. Note that the VW cleaner stands above the carburetor air inlet, usually by 4 to 6 inches. This design contains the fuel fog (stand-off) and allows it to mix with the incoming air. With a flat filter sitting right on top of the air inlet you will cause the fuel stand-off to fall back into the carburetor. This creates an over-rich mixture. If you have already bought such cleaners, they can be used if you will mount them on a 4-inch-long length of tubing which is approximately the same size as the carburetor air inlet. It is this fuel stand-off problem or condition which causes the 4-inch-high velocity stacks to work so well as compared to a VW being run without an air cleaner.

Naturally, the next thing to do is to bring the carburetor or carburetors up to the latest-year specifications as shown in the Service Manual. Of course, you'll want to make sure that the carburetor is cleaned and that the float level is correctly set. Also, refer to the discussion on VW smog devices.

In general, the VW main jet is too small for maximum performance, even though it's correctly sized for economy. The latest models with low emissions are jetted so lean that the engine runs hotter than would otherwise be necessary. For best performance from PICT models, you should use a main jet from 125 to 135 and a 135z or a 150z air-correction jet. Even larger jets are sometimes required to get the correct mixture, especially if other modifications to the engine have improved its breathing capabilities.

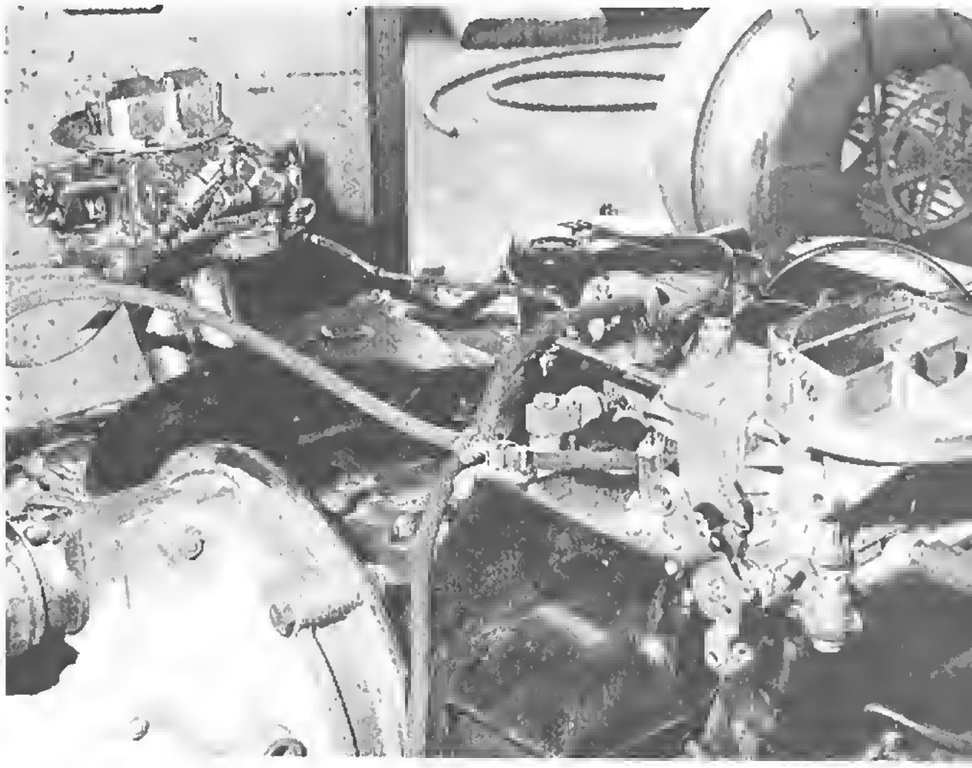
40 HP engines equipped with 28 PCI carb with stock 21.5 mm venturi require at least a 122.5 main and a 180 air-correction jet. 24 mm replacement venturis can be installed to get more upper-RPM horsepower, but you'll need to change to a 140 or 145 main and a 160, 170 or 180 air, depending on the individual engine.

Changes which can affect carburetion in this manner include larger valve sizes, bigger displacement, ignition timing, high-lift rocker arms, special camshaft, changes in compression ratio, elimination of exhaust heat, etc. An efficient exhaust system greatly affects the engine's overall breathing ability.

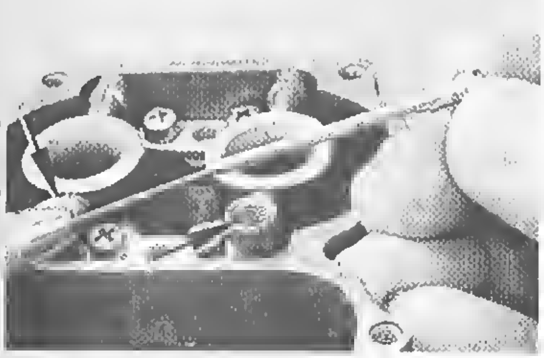
You may be tempted to rip out the choke(s) until you look at the carb to see that there is so much area around the choke—as compared to the tiny venturi which is being supplied—that there's no way to get more air through the carb by taking out the choke. Taking out the choke causes further wasted effort because then you still have to plug the choke-shaft holes so that all air entering the carb still comes through the air filter.

Without removing the throttle plate and shaft, smooth the venturi's surface with special attention to the leading and trailing edges. Check carefully to make sure that you eliminate rough casting marks which could disturb the air flow. Use abrasive paper to smooth the venturi and the inside of the carburetor air horn.

More air can be stuffed through the carburetor if you install a larger venturi or remove the venturi entirely (only possible on the older 28PIC model) leaving an opening approximately 28 mm in diameter. Formula Vee racers did this until the rules disallowed it. The main jet/air-correction combination in this instance should be about 145/180. Solex also offers 23 mm and 24 mm venturis for the 28PCI. Solex P/N for the 24 mm is 53354. The VW industrial 1600 engine has a 30PCI with removable venturi. If you install a 30PCI or 30PICT on a "28" manifold, you'll have to file the flange to accept the slightly wider stud pattern. The 32PDSIT carbs used on the fastback/squarebacks also have removable venturis.



Bucks-down racers can appreciate the possibilities of using two 500 cfm Holley two barrels on a VW. We didn't get enough running time on these but did discover that they should come close to 48 Webers with a little more work. Slot under carb base was required to avoid mid-range richness. Their $49 price is definitely intriguing.

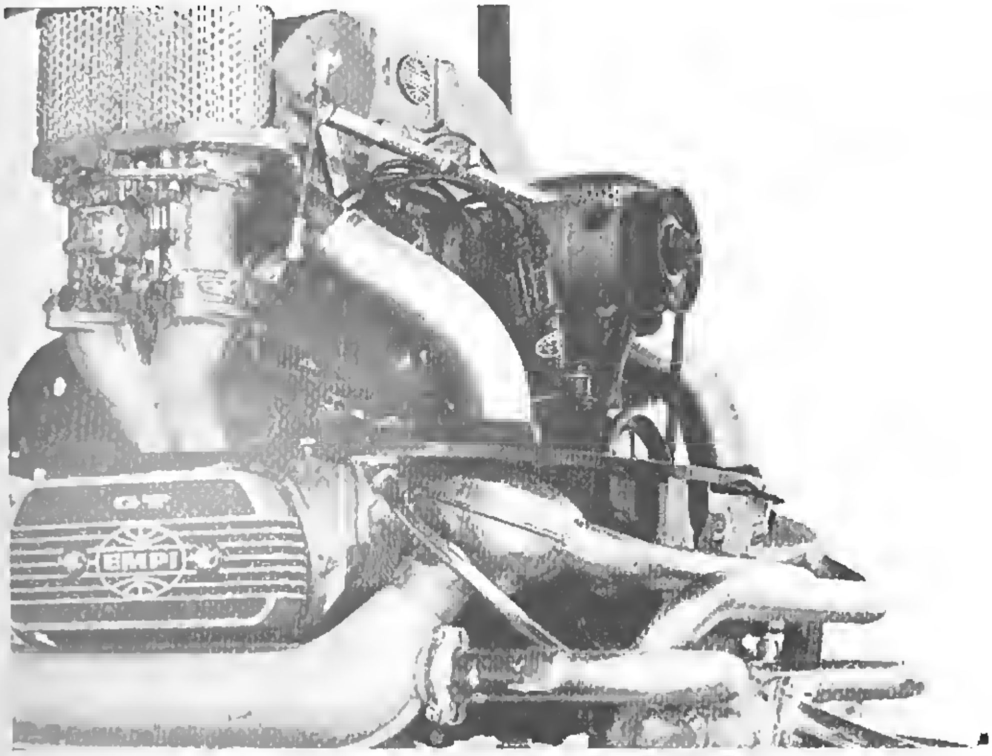


A set of wire drills and a pin vise are all you need to open up the idle feed restrictions on the Holley Bug Spray carburetors if you have a flat spot off of idle. Enlarge jets 0.002-inch at a time until you have the problem cured. If you go too far, the tip of the jet can be soldered closed and redrilled to the smaller size needed. Arrows indicate holes where idle feed tubes screw into carb.

Still further improvement is available by cooling the mixture, assuming that you are sweltering in summer's heat—because this is something that you don't want to do in wintertime or you'll get carburetor icing. Eliminating the exhaust flow through the heat riser passage is accomplished by cutting a piece of tin to block the passage. A piece of tin can will work fine. Just loosen the attachment of the heat riser at the right side of the engine and slip the tin in so that it blocks the exhaust which would otherwise flow to the left side of the engine. Our dyno tests showed that this simple trick added horsepower with no other changes.

To cool the mixture even further, use a "cool can." These standard items for the gung-ho drag racer consist of tubing coiled in a container which will hold ice or dry ice to cool the fuel before it gets to the carburetor. The fuel line is merely cut so that the cool can can be inserted as a section of the line. The improvement in HP is minimal, but every little bit counts in drag racing.

According to V Speed & Sport's Don Baker, the 28 PCI does work well with the venturi remove and he says, ". . . for Formula Vee the venturi can be honed out so far that yo have to glue it in to keep it from collap While not legal for Formula Vee racing, the carb can be improved for drag classe by contouring the flange where the two halves of the carburetor meet. There is usually a casting flash which greatly impedes air flow. Because there is no high-speed circuit in the VW carb, you have to make your own through the use of the accelerator pump discharge nozzl This nozzle usually drips a couple of squirts of gas when you open the thrott because of the vacuum created around t venturi. But, in mass production the mating surfaces of all Solex carb halves (including 1971's!) are not perfect and a vacuum leak invariably occurs so that on a little gas is squirted. If these two surfa are made smooth and flat and then glue together—there will not be any vacuum leak and you'll get more gas when the throttle is fully open. A piece of Wet-or-Dry 400 paper supported by a piece of glass and flooded with solvent makes it



EMPI-equipped display engine at Economotors Volkswagen in Riverside, California. Exhaust headers have heater boxes for fresh-air heating system. Dual Solex carbs mount on EMPI manifolds angled forward to fit into engine compartment. Throttle-linkage mounts make a base for the paper air cleaners—a neat design touch.

easy to surface these parts to a fine finish. Also, it doesn't hurt to open up the passage between the accelerator pump and the nozzle. For competition, the leading edge of the butterfly can be filed to a sharp edge—which leaves gaps when the throttle is closed—fouling up the idle and off-idle performance. For Vees, this is no problem because the wide-open-throttle position is the one that's important." As of 1971-72, Vee manifolds were regularly being opened up on the inside by "chemical milling," an acid-dipping process which opens up the inside diameter.

VW MANIFOLD

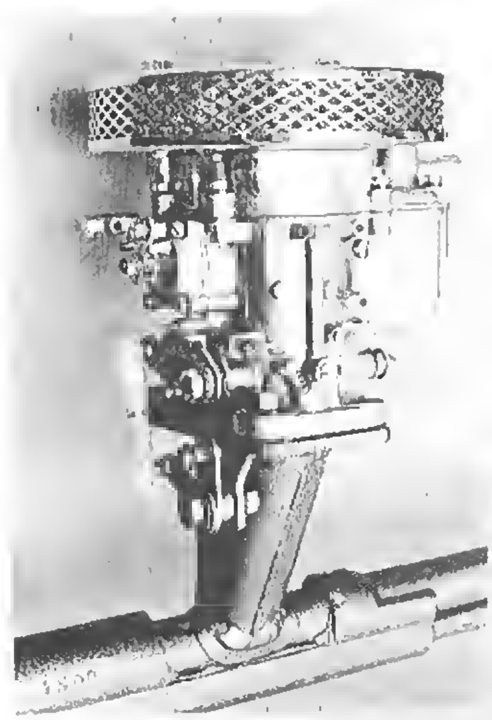
Manifold tube size is really important on the VW. The tiny stock manifold is a built-in performance limiter. It progressively chokes off breathing as engine RPM's are increased. Its size is directly related to the amount of horsepower VW wants from the engine: 40HP - 0.940 or 0.990-inch outside diameter; 1300 - 1.125 outside diameter; and 1500 - 1.230 outside diameter.

You cannot just stack more carburetion on top of the stock manifold. Don't be tempted to put a bigger jug on the stock manifold just because low-cost adapters are available. Spend your money on something that adds HP. Some uncaring manufacturers have built a big carburetor flange onto the stock manifold, painted it pretty and sold it with a famous-name carburetor for a fancy price. Our tests of one of these showed less than stock performance through the entire engine range. HP equal to the stock, single-throat carb could not be obtained because the stock-manifold area will not work with the larger venturi area of a bigger carburetor.

The easiest and least-expensive performance improvement is obtained by installing a new manifold with a centered two-barrel carburetor. This should be one of the first performance modifications which you make to your VW, unless you are competing in a class where such is not permitted . . . or where you have to use two two-barrel carbs or fuel injection to be competitive.

It should be noted that center-mounted carburetor arrangements must have carburetor heat during cold weather. The air supplied to the carburetor intake can be preheated or by the more usual use of exhaust heat to warm up a spot just under the carburetor base.

Center-mounted carburetors are not usually "ram-tuned"—regardless of what you may read in the advertisements or racing catalogs. Ram tuning requires a "tuned length" of manifold from the inlet valve to the carburetor venturi—or to a chamber below the carburetor. This is easily accomplished on dual-port VW heads by using individual pipes from each port to a chamber under the carburetor, but it is difficult to obtain



RPM manifold is merely a funnel welded onto stock VW manifold. We couldn't get stock HP out of it in our tests, regardless of the expensive Weber it supports.

any useful ram effect with single-port heads except over a very narrow RPM range . . . certainly not throughout the RPM range as is often claimed.

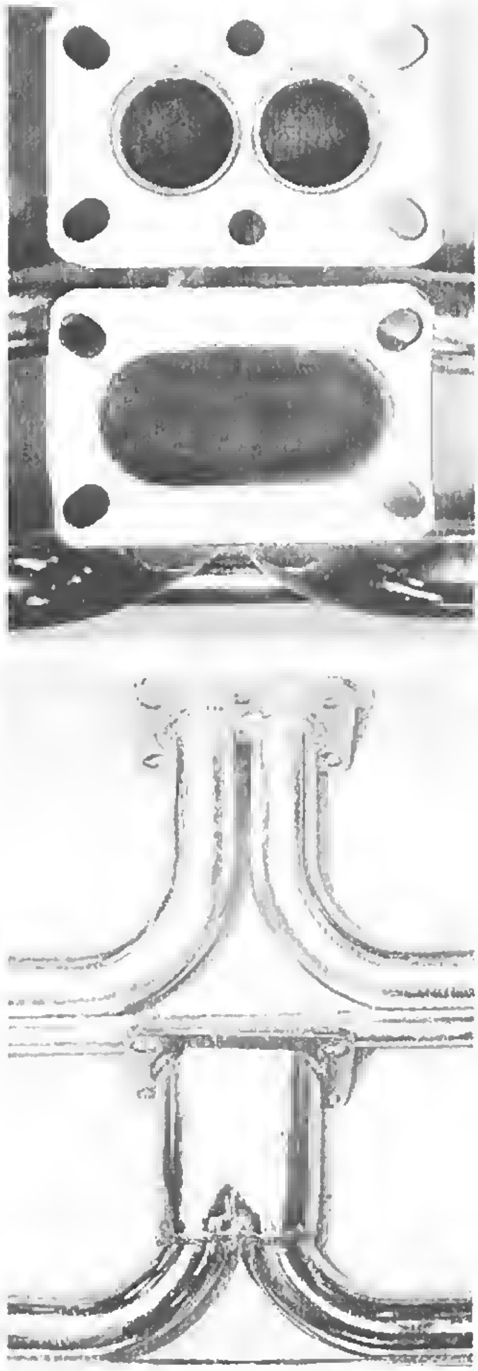
Before 1969, several VW manifolds for centered two-barrel carbs were available. These were made from tubing which was 1-1/2" diameter or larger. In 1969 several tuners made dyno tests which compared the performance of a two-barrel carb on a 1-1/2" tube manifold with the same carb on a 1-1/4" tube manifold. In the critical street-driving range of 2500 to 3000 RPM, the 1-1/4" tube manifold with a Zenith 32NDIX carburetor gave two HP more than the 1-1/2" tube manifold.

Dual-throat carburetors which can be considered for your VW include the Holley RS-4691, Zenith 32NDIX, Weber DCD and DCN and the Carter VW model.

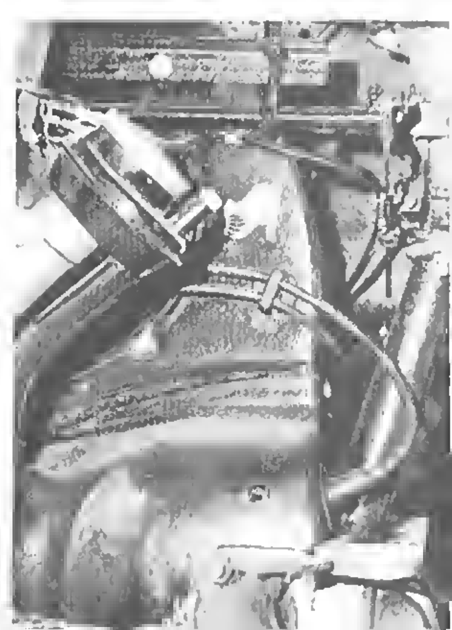
Dual-carb-equipped VW's with single-port heads can get more HP by replacing the two stock 23 mm venturi carbs with a single two-barrel carb. As an example, the two 29 mm venturis in the Holley breathe enough better to provide a dramatic improvement in performance, especially with a bigger-than-stock-displacement engine.

PLENUM CHAMBERS OR SLOTS

Adding a slot in the base of the carburetor or creating a cavity (plenum chamber) below the carburetor mount "cushions" the manifold pulsations to eliminate the VW's fuel "fog" which stands about 6 to 8 inches in the air above the carburetor inlet at high RPM when no air cleaner is used. It also assists at high RPM by adding several HP at 5000 RPM as compared with a 1-1/4" tube manifold without the slot or chamber below the carb. A plenum chamber softens the harsh pulses in the intake system. The larger the chamber, the more the softening effect. As the pulses are softened, the incoming air stream does not pull as much fuel from the discharge nozzle, so the mixture curve is definitely leaned out at high RPM. The cure is to jet the carburetor excessively rich so that the mixture will be correct at the top end, but this richens the curve throughout the RPM range. The result is worsened mileage and a "soggy" mid range.



Comparison of isolated-runner manifold (top) with plenum type shows that "plenum" means a plain 'ol hole underneath the carburetor—nuthin' magic 'bout that. Bob Waar photos.



A lot of VW enthusiasts still think that two stock Solex carbs will produce more HP than a single centered two-throat. A single two-throat is definitely better and less costly—plus there are no synchronization problems.

LOOK BEFORE YOU BUY

Don't be mis when buying a centered two-barrel ma fold, especially a used one. Get one w tubes no larger than 1-1/4" for single-p heads, no larger than 1-3/8" for dual-p heads. Make sure that the tubes have t correct center-to-center spacing and an to fit your engine or that they can be bent to fit. The carb flange should be positioned about one inch off center to the left high enough so that the levers and choke mechanism will clear the ge erator.

40 HP ones have ports at 90° to the m fold runners; 1300's, 1500's and 1600' have ports requiring a manifold with runners slanting toward the center of t engine; and dual-port heads require ma folds uniquely constructed to fit the fl surface around the two ports. You sho also be careful to buy a manifold whic has been designed for use with the carburetor which you have selected.

If a manifold is more than 1/4" too wide c too narrow to fit onto your engine, yo can cut the manifold apart and reassen it with a short length of fuel-grade Neo prene hose clamped at each end. Othe wise, the runners can be carefully bent that the manifold will fit.

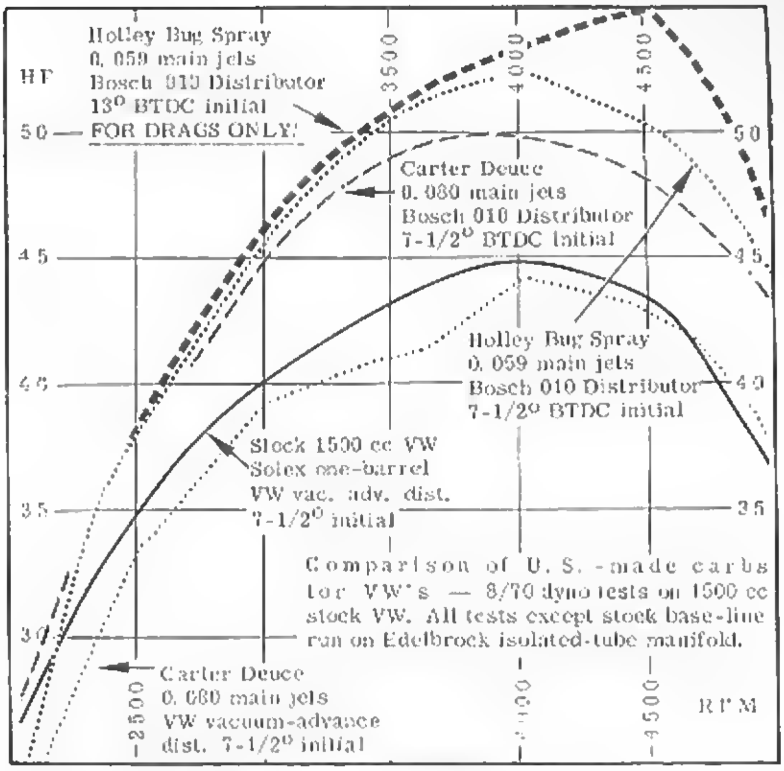
If the carburetor mounting flange is offset too far to the left, the throttle linkage will be always operating "in a bind." There's no real cure for this except to take the manifo back and get your money back so you can go elsewhere to buy one that fits. sure that the carburetor does not fit tightly against the fan housing. This could cause the fan to rub the housing.

INSTALLING A NEW MANIFOLD

Installing a new manifold is easy if you know what is needed, so here's a quick check list for doing the job. Reassembly is merely the reverse of this procedure.

1. Disconnect thermostat flap valve or rod.
2. Remove fan belt, generator strap and electrical connections to generator, tagging the wires so that you'll get them on right in reassembly.
3. Remove vacuum and fuel lines and disconnect throttle cable. Disconnect wire to electric choke and/or fuel shutoff valve.
4. Remove two bolts which hold fan housing to flywheel side of case and two nuts at each side of the manifold at the head. Remove two nuts holding manifold flange at each head.
5. Remove two bolts attaching each heat riser and remove heater ducts at each side of the fan housing.
6. Lift entire fan housing off with the generator intact. Don't disassemble any more than is absolutely necessary because this makes the job take that much longer.
7. Remove manifold with carburetor and remove old gasket from each head.

When reinstalling the manifold or a new manifold, measure the travel required to move the throttle arm from idle to full-open position. Before installing the throttle cable, check that it provides at least that much movement when the accelerator pedal is operated. Always check to make sure that you get full throttle after the manifold is installed. And, be sure to check that the throttle-return spring is installed and working.



As you'd guess from the venturi sizes of the Carter Deuce vs. Holley's Bug Spray, Carter comes on strong at low RPM but drops advantage by 2500 RPM. Holley grabs additional 2 HP by 4000. Both carbs should be jetted richer than dyno runs for use in car. 0.060 mains in Holley are right on, but Carter needs 0.081 or 0.082 mains instead of 0.080's supplied, unless restrictive air cleaner richens Carter to acceptable ratio. Both require centrifugal-advance distributor. Note that Carter won't produce stock HP with vacuum-advance distributor. Extra advance can be cranked in for more ponies at the drags as shown here, but the *engine must be cold*. Return distributor to stock setting before running on street or you'll fry plugs, melt pistons and generally destroy your engine.

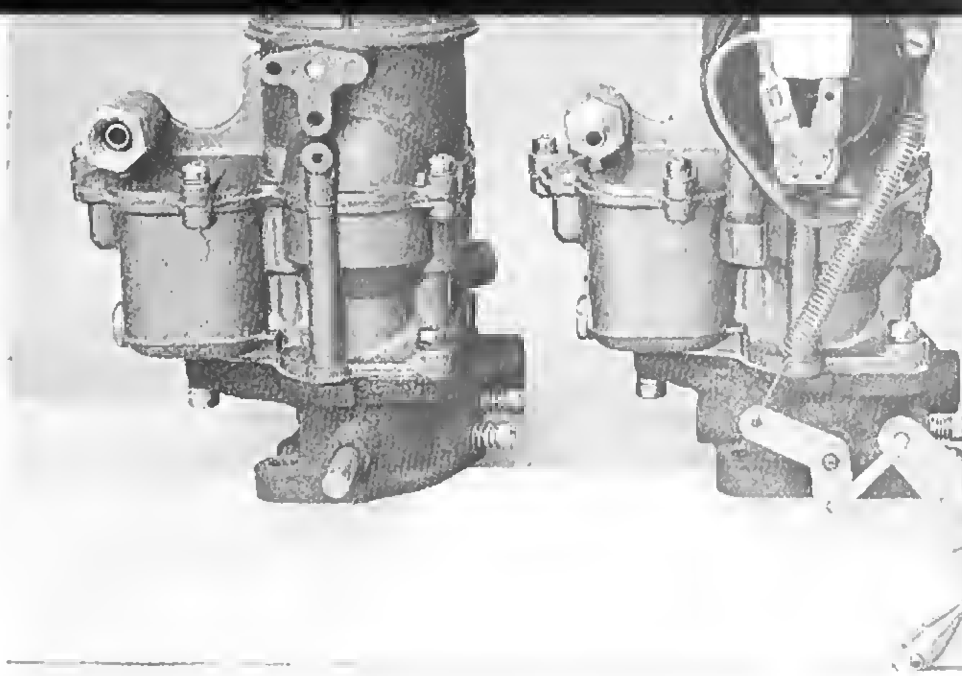
HOLLEY BUG-SPRAY: 200 & 300 CFM

Holley has two carburetors specifically designed for use on the VW. My own tests, as shown in this book, were made with the 300-CFM R-4691 which was introduced in 1970. It consistently produced more HP throughout the driving range than any other carb which I tested for the VW. But, unfortunately, the 300 CFM flow capacity of the carburetor is too big for any VW smaller than about 1800 cc or larger. Hence, the use of the R-4691 on a 1600 cc or smaller VW engine results in a very large flat spot off of the idle. For such engines the 200-CFM R-6244 should be used. Prices are about $60 and $53, respectively for the 300 and 200 CFM units.

At these low prices, the carburetors are as vital for VW owners as Holley's winning four-barrels are for Chevy, Ford and Mopar builders.

Old hotrodders may recognize the two carbs as being quite similar to those used on 1949-53 Ford V-8 flat-head engines. They are *similar*, but the internal venting, passageways, etc., were completely changed in a year-long program involving flow benches, road tests and dyno tests.

The carburetors have either 15/16" venturis (23.75 mm in the 200 CFM) or 1-5/32" venturis (over 29 mm each in the 300 CFM), revised low-speed (idle) and progression circuits, new booster venturis, new pump shooters, relocated pump vent and a special needle and seat. The four-bolt cast-iron throttle base has a pivoted arm which connects to the throttle-shaft lever by a rod. The throttle lever has its own strong return spring so that the carb will idle when you let off of the gas. The pivoted arm has an adjustable cable end which slips over the end of the VW throttle cable where you can secure it with a socket setscrew. This cable end allows 5/8" adjustment so that you can be sure to get full throttle opening. When you actuate the pivoted arm, you'll note that the first half of cable travel opens the throttles about 1/3—and the last half cranks the throttles the rest of the way to fully open . . . giving a variable-rate or progressive throttle action.



Holley Bug Spray (right) compared with old 3-bolt model shows superior equipment o late version: throttle linkage, electric choke and fuel fitting.

The choke is electric with a connection for the VW choke wire. It works on 6 or 12-volt systems. The fuel inlet is designed so that you merely slip the stock fuel hose over it. Be sure that you are careful not to shave any rubber from the inside of the hose as you install it because this would cause needle hang up and flooding of the carb.

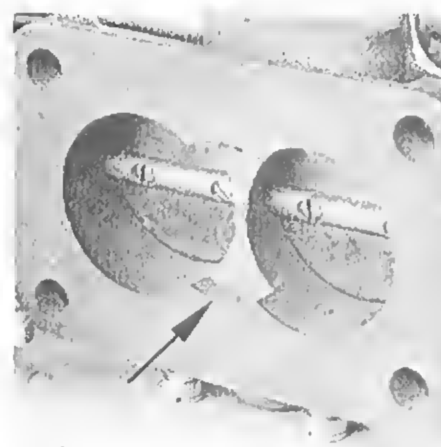
Holley engineers recommend bolting the carb to an isolated-tube (non-plenum) manifold which has a flange directly connected to the 1-1/4" tubes feeding the cylinder head. A balance slot in the carburetor's base connects the two throttle bores. Tests showed that any additional balance chamber or plenum carves a big "hole" out of the performance curve and creates a noticeable "stumble" from 1500 RPM up on hard acceleration. *A slightly larger plenum* chamber might be helpful on an engine designed to spend most of its life above 5,000 RPM—a rare situation, even for a car destined solely for drag-strip attacks—which would probably use two carbs on separate manifolds anyway. Installing the carb on a manifold which was designed for the Zenith (and not including a plenum chamber) may require dimpling the fan housing about 1/2" to clear the front of the carburetor. And, you may find that the carb-mounting flange is about 1/2" too far to the right and too low—thereby allowing the accelerator pump and choke linkage to hit the generator, especially on 1500's. If this occurs, rebuild the manifold to raise the flange, or get a new manifold. Don't attempt to raise the carb with an adapter unless it has two straight holes the size of the throttle bores—you don't want to put a cavity under the carburetor for reasons already discussed. The Holley is extremely sensitive to the idle-mixture adjustment.

If there is a flat spot off of the idle with either the 200 or 300 CFM Holley, then some opening up of the idle fuel restriction is required. You'll have to use a set of wire drills to get the idle opened up 0.002" to 0.004" at a time from the stock 0.031" diameter used in the idle tube.

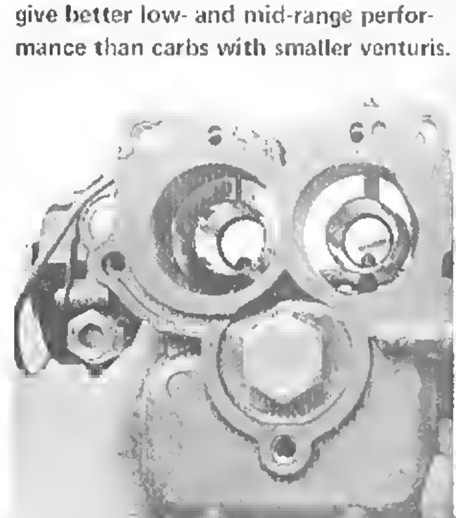
If you had been planning to use a plenum-type manifold under either of these carburetors, DON'T! You'd have to go 'way rich on the idle mixture and also install about a 48 main jet in the 200 CFM Holley, a 64 in the 300 CFM or an 82 in the Carter to get the mixture rich enough at the top end—and this will make the mid-range so rich that all your economy will go out the window.

The stock vacuum-advance distributor has to be replaced with an all-mechanical-advance distributor when installing the Holley because there is no vacuum takeoff in the carburetor.

As you can see from the HP charts, two Holley Bug Sprays work so good that you may have a hard time convincing yourself to pay an extra $100 or more for the privilege of saying that your engine has Webers. Gene Berg offers a complete dual Holley setup with carbs, manifolds, fuel lines and linkage for about $150.



Balance slot in carb base eliminates any need for larger plenum; dampens air-flo pulsations to eliminate fuel stand-off. Below, carb base removed. Solid plug replaces power valve. 1-5/32" venturis (29 mm) work with booster venturis to give better low- and mid-range performance than carbs with smaller venturis.



ZENITH

ZENITH 32NDIX dual-throat carburetors are a very popular carburetor used on many foreign cars, including Porsche, Simca, Ford Vedette, Daimlers, etc. Some of the carburetors have been specifically set up for use on VW's and these are typically supplied with 24 mm venturis, 135 main jets and 180 air-correction jets. The fast way to identify one of these $75 carbs is by the VW-style throttle arm. Idle and progression circuits in these carbs are approximately correct for the VW. You'll see similar carbs without the correct throttle arms. Because these arms are not readily obtainable, the logical thing to do is to weld on a piece of a throttle arm from a Solex 28-30PIC/T carburetor, keeping the angles and length similar to the stock VW installation so that the throttle cable will work correctly. Dean Lowery points out that it's important to check that the throttle is opening because some "offbreed" rebuilt Zeniths have accelerator pumps about 1/4" too long and won't give full throttle.

Venturis are interchangeable. If you get a Zenith with 21 mm venturis, the larger ones can be installed. However, for a street machine or off-road vehicle which is being used for fun, the smaller venturi will provide excellent mid-range pulling power. Jets and venturis, although not widely available, can usually be located by checking with several of the VW performance experts, especially in the Los Angeles area.

Zenith 32 NDIX on EMPI isolated-tube manifold. Engine number starting with "H" identifies this as a 1500 engine. Tiny line to oil-pressure gage is inadequate for fast response, should be at least 3/16 inch.

Other carburetors now available will provide more performance than the Zenith at less cost, so the use of this carburetor—long a standard item for the VW hot-rodder—should fade fast. It's a good carburetor and if you can get one for the right price, it'll be fine for a street machine or off-road vehicle.

The Zenith has no slot in its base and therefore provides best performance when used with a 1-1/4" manifold with a small plenum chamber directly under the carburetor.

The stock vacuum-advance distributor has to be replaced with an all-mechanical-advance distributor when installing the Zenith because there is no vacuum takeoff in the carburetor.

SOLEX 40 P11

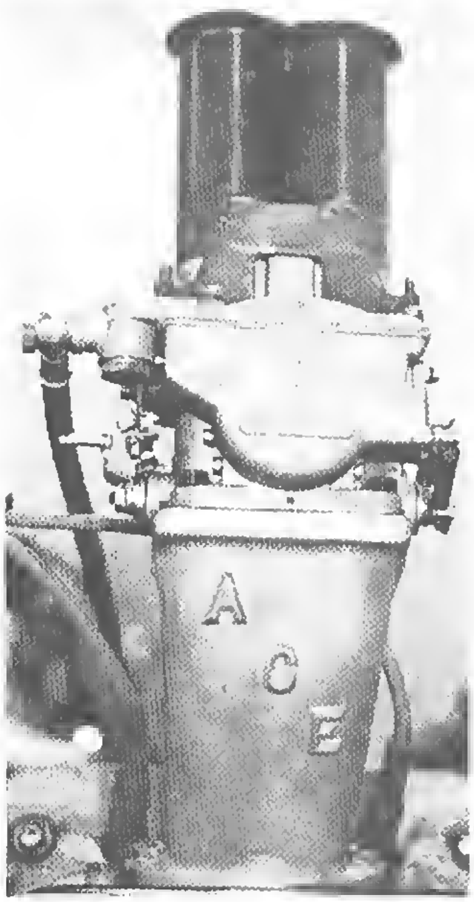
This Porsche carb is quite often used in pairs on dual-port VW heads, but increases in its price to $125 have dampened its popularity. The calibration (jet sizes, etc.) in the "smog" models—identifiable by a golden-yellow alodine finish, tagged 616-108-103-01—requires changes to a 28 mm venturi, 125 main, 180 air and 25 emulsion tubes. 30 mm venturis are the largest which can be used. In the older 40 P11 4 aluminum-color carbs, 32 mm venturis will fit but they create an off-idle "bog" problem which is difficult to fix.

CARTER DUNE-BUGGY "DEUCE"

This Carter WGD two-barrel was originally used on 1949 Packards, 1955 Chevys, Hudsons, Oldsmobiles and Jeeps—and a few others thrown in for good measure. Although it looks like an old timer, this $50 unit has been completely changed on the inside. There are so many changes that you'd have no chance of making a junkyard WGD operate on a VW.

It has two built-in 27 mm venturis (1-1/16") which let it flow enough air to provide more HP than the old Zenith or even a 40 DCN Weber with 24 mm venturis. The throttle lever is equipped with a hex socket screw to secure the VW cable once you have drilled both sides of the fan housing to reposition the throttle cable tube to the left. An electric-choke has a fast-idle link to keep the engine running on frosty mornings. The choke will work with either 12V or 6V systems. Leave the choke installed because you won't gain any HP by pulling it out, you'll just have two more holes to plug to keep out dirt and dust.

The carburetor has a sophisticated metering-rod system to provide the correct mixture for the load your engine is pulling at any time. Each of the rods centers in a main jet, and there is a rod and a jet for each venturi. The largest diameter on the rod is fully inserted into the jet at cruising so that the mixture is leaned out. A vacuum piston attached to the metering rod hanger is held down by manifold vacuum which

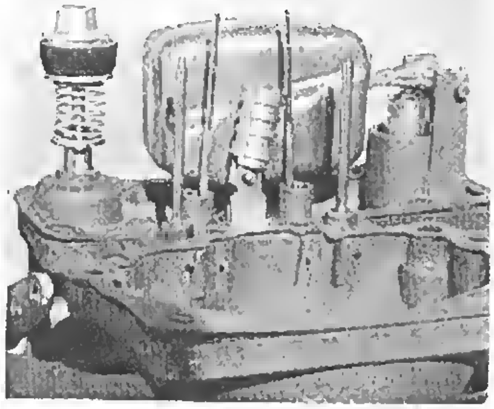


ACE manifold with Weber carburetor. Note that the manifold passages start large to match the carb base and throttle openings, then taper smoothly into port size. Stacks are fabricated by same firm.

overcomes spring tension under the piston. When the engine "sees" a load, even if you fail to open the throttle a tiny bit more, the manifold vacuum instantly moves toward atmospheric pressure and the piston is raised by the spring so that the mixture is richened. This raises the rods out of the jets. When you floor the throttle, the linkage overrides the vacuum piston to lift the rods to their minimum diameter in the main jets, giving a full-rich mixture.

When you buy one of these carbs, be sure that you get the second version which has a built-in air vent from the metering-rod chamber into the air horn. The first version vented through a hole to the outside, which obviously was not the answer for off-road or even a dusty street. If you got one of the first of these carbs and find that the engine jumps or lurches at part-throttle cruising, you'll have to install a 0.028-inch restriction in the hole which applies vacuum to the underside of the metering rod piston. This will smooth out the vacuum so that the piston will not jump up and down from the VW's manifold vacuum fluctuations. You'll also have to modify the fuel-inlet fitting on the first versions, making it the same diameter as the one on your stock Solex. Otherwise, your stock VW fuel hose, which is the best kind available for any VW application, won't fit.

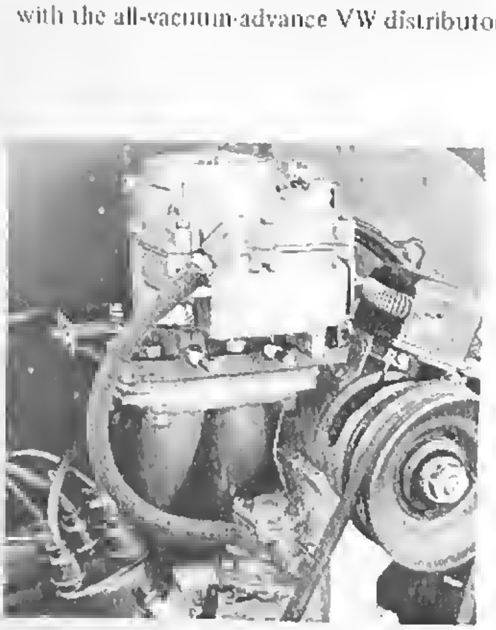
The Carter carburetor must be used with a centrifugal-advance distributor. Although Carter's first ads said that the carb could be used with the stock distributor, this was wishful thinking because the carburetor won't produce stock HP if installed with the all-vacuum-advance VW distributor.



Carter Dune Buggy "Deuce" requires careful insertion of metering rods and vacuum piston when reassembling carb after making jet changes. Definitely a tricky operation at best.

ROCHESTER 2-GC

This is a carburetor for big-inch V-8's, *period*. Never mind trying to use it on your VW. You'll blow your mind in the process because there's just no way to make it work right.

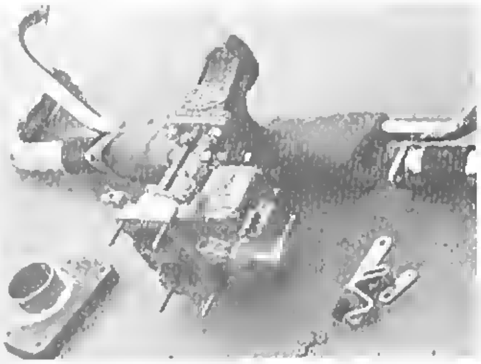


Rochester 2 GC carbs with 28 mm venturis should produce a lot of HP, but the one we tested merely equalled stock HP at 4,000 RPM and lost HP above that. The right place for this unit is on your GM-powered tow car or truck.

WEBER CARBURETORS

Several types of Weber carbs are used on hotrodded VW. Most common are the 48 IDA, 35-38-4 DCNL, and the 40 DCN. These dual-throat carbs are usually used in pairs. Some work better than others. Progressively opening dual-venturi Webers such as the 28/36 DCD and the 32/36 DFA' (from the Ford Pinto 2.0 liter engine) : starting to be used in larger numbers as centered single carbs.

The popularity of Webe carburetors for racing can be best explained by the fact that the carburetors are used on automobiles which are not produced in large quantities. In the U.S. any production run of an automobile is large enough to warrant building a carburetor which is designed exactly for the engine, transmission, etc. Interchangeab jets, etc., are kept to an absolute minim In fact, only the main jet can be change in most U.S.-made carbs. But where a number of manufacturers must use versions of the same basic carburetor, the basic carburetor must be adaptable to th different air-flow requirements of the several engines on which it is used. Most Weber carburetors can be varied in all aspects to permit such adaptations: venturis, idle jets, idle air jets, main jets, air-correction jets and emulsion tubes. Thus, they are more easily tailored for racing applications.



Weber 28/36 DCD carb mounts on casting in center of EMPI manifold. Carb's primary/secondary barrels are progressive-acting with 28 mm as primary throttle-bore size. Because manifold steadies against fuel-pump mount, electric fuel pump is required. Casting at left connects carb to stock VW air cleaner. Manifold also works with '71 dual-port adapter castings.

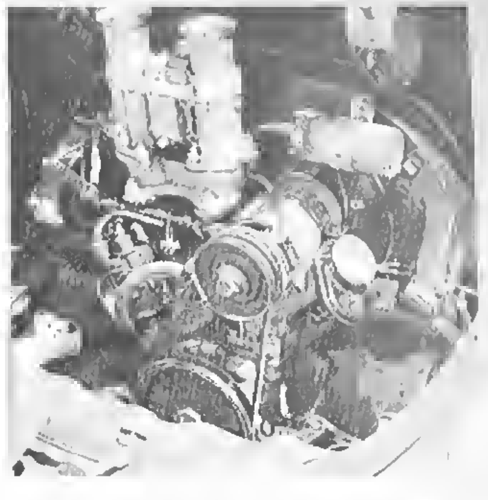
48 IDA Weber carbs in back of Pete Barker's 128.893 mph VW sedan (1969 Bonneville National Speed Trials) are fed ram air from front duct which also supplies cooling air. All areas of carbs are pressurized—not just the throats—and this is the correct way to do it. 82 X 88 mm engine has SPG roller crank and EMPI/Mahle forged pistons. Aero-Quip steel-braid-covered hoses feed oil from pump through full-flow AutoLite filter to case.

However, it is important to note that the name Weber does not insure that you will automatically get more HP—not unless everything is absolutely correct—because it is possible to pay Weber prices and not get what you might expect as Weber HP. For instance, at the beginning of my tests for this book, I bought an RPM manifold with a dual-throat progressive Weber. Not only were the directions totally in error, the carburetor would not produce stock HP because it was mounted on a cobbled-up stock manifold. The tiny cross-section of the stock manifold couldn't make it. These are still being sold at prices ranging up to $155 (with an extra charge of $15 for "correct jetting"), believe it or not.

48 IDA 4 Weber

Porsche 904 Carrera engines used these carburetors. They were originally imported by Carroll Shelby for use in sets of four on 300-inch V-8 Ford racing engines. So many were imported that at one time they glutted the Southern California market, dropping to prices as low as $50 or $60 each. Now you can expect to pay $140 each and with inflation rampant, chances are good that it'll soon take the better part of three $100 bills for a pair. Joe Vittone picked up the first set from Shelby and installed them on one of EMPI's early drag engines. From that minute on, the "thing to do" was to hang a set of Weber 48's on your VW racing engine. As you will see at the conclusion of this discussion, progress in VW carburetion was possibly slowed for about five years or so because so many VW tuners were of the "monkey see, monkey do" variety.

Before buying a set of 48's, be sure that you know what the price includes. It's best to buy from a firm which will agree to help you to jet the carb and to swap parts with you at no charge until the carbs are running right. Obviously, the selection of the correct venturis should depend on the size of your engine and the RPM which you intend to twist it. The carbs come from the factory with 45mm venturis, 1.70 mains, 1.20 air corrections and F7 emulsion tubes. No VW teapot is going to suck air like a 300-inch V-8 revolving at 7 grand. It's a wonder that these carbs will work at all on the VW, but—if you throw the 45mm venturis away and



Single 48 IDA Weher mounted on centered manifold will soon cost you enough in gasoline expense to have paid for dual 40 DCN's or dual 38 Webers in the first place. 8 mpg is not uncommon with this arrangement. Bob Waar photo.

switch to something between 32 and 37mm, with a corresponding change to 1.35 main jets—the carbs will run well at high RPM. The shop which sells you the carbs should equip them with 32 or 34mm venturis for a street/drag engine—or 36 or 37mm venturis for an all-out drag-race engine with a super-wild camshaft. The latter will probably require 1.40 main jets. 48 Webers imported at the end of 1970 were specially equipped with 37 mm venturis, but don't make any assumptions that the ones you are getting are so equipped.

Keep in mind that your engine will never be completely "right" in the low end of the RPM range, but will definitely come into its own above 5,000 RPM.

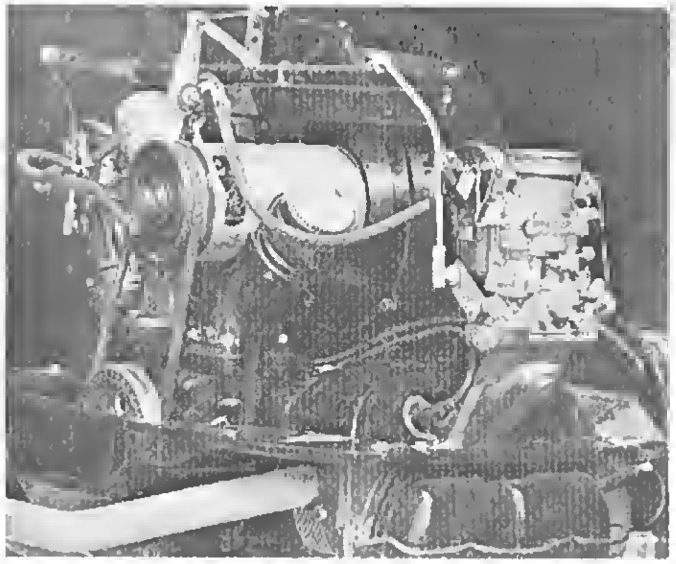
Expect mileage on the order of 8 to 10 miles per gallon, especially with 35 to 37 mm venturis.

Since many VW owners have already paid prices of $350 to $400 for a pair with manifolds, linkage and fuel lines, it is important to point out that you can get more usable HP for most driving by using other Weber carbs. The 35 or 38 DCNL with smaller throttle bores will out-perform the 48IDA's up to about 6,000 RPM, at which point the larger carburetor may begin to give some additional performance. But you get this added performance at the expense of smooth operation through the RPM range

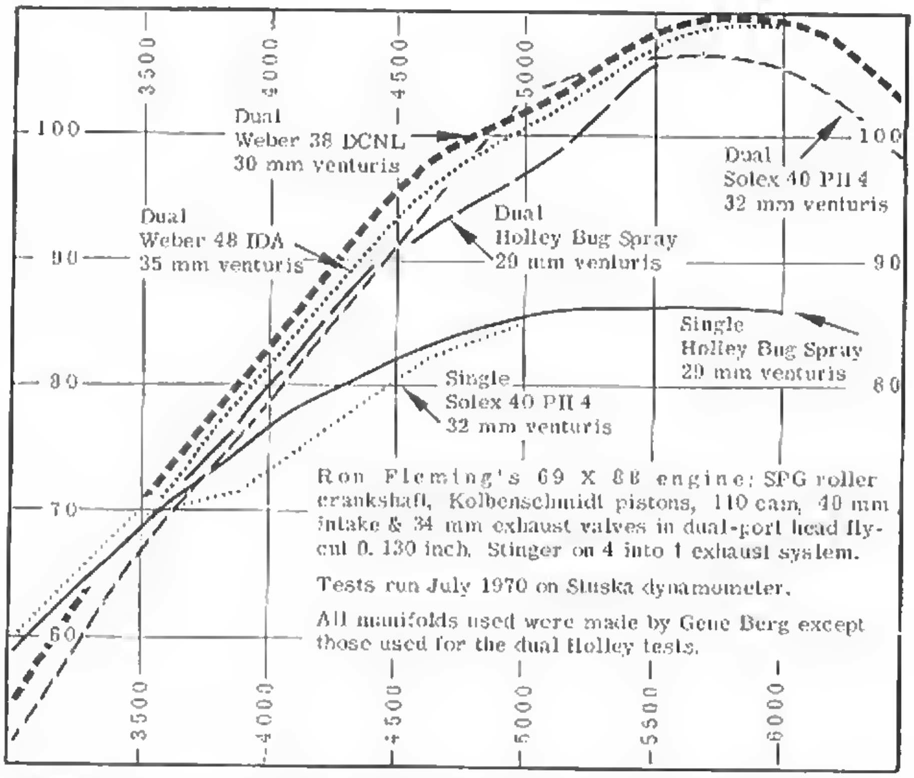
below 6,000 RPM. The 35's and 38's have an added advantage in that they work right when you take them out of the box, in most instances. No special venturis have to be made or installed and the stock jetting is close to perfect. The Weber's complexity, in terms of the changeable main, and idle fuel and air-bleed restrictions, makes the 35's, 38's and 40's the best buy for VW owners wanting ultimate HP. Not only that, these smaller carburetors cost at least $50 less than correctly jetted and venturied 48 IDA's. And, you get mileage with the smaller carbs, too. Expect about 18 to 22 MPG on the road, even with a wildly modified engine. These guzzle less gas than the 48's because they are better suited to the VW's size and RPM capabilities.

35 DCNL 2/3, 38 DCNL 5 and 40 DCNL

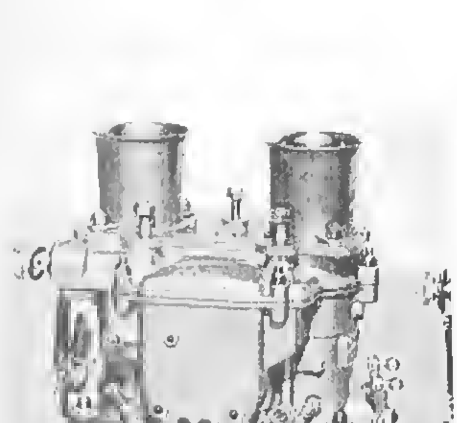
These $100 Webers, used mostly on Lancias and Maseratis, can be fitted onto ACE, Berg and EMPI manifolds. There are different bases to be considered, so buy the manifolds with the carburetors. Prices for a pair with all the fixin's range from $300 up. 38 DCNL 5 and 35 DCNL 2/3 carbs are factory-equipped with 30 mm venturis, 1.30 mains, 2.40 air-correction jets and F11 emulsion tubes. These carburetors are now obsolete and are not available as of 1972.



Dual Holley Bug Sprays equalled expensive Solex dual-throats at 5500 RPM.

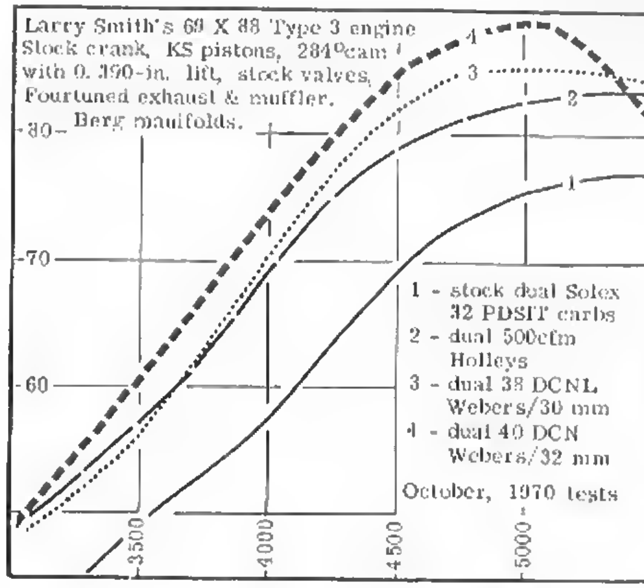


Revealing tests show that you may be able to get by with something other than the expensive Webers if your pocketbook looks as if it had been on a diet. The least-expensive carbs—dual Holleys—were the big surprise in this series of tests, pulling within 3 HP of the best Webers at 5,500 RPM—and besting the dual Solex's except for the narrow range between 4500 and 5500 RPM. Don Gonyou of Holley suggests that the "sag" in performance at this point may be at least partially correctable by providing additional plenum or balance volume between the isolated stacks of the manifolds to correct mid-range richness. Note that the 48 IDA Webers were clearly too big for this engine up to 6,000 RPM, at which point it looks as if they would hold the power on out farther than the 38's, which are starting to fall off with the 30 mm venturis which come in them. 38 Webers equipped with larger venturis would hold the HP to a higher RPM level. Single-carb tests were run on prototype Berg manifolds using castings at each of the cylinder heads—months before the factory announced the 1971 arrangement.



Weber 38 DCNL carbs work well on VW's, or use the newer 40 DCN's. Berg manifold.

40 DCN Webers—a pair—really turned on Larry Smith's flat VW engine (see dyno charts). Berg universal manifold works with Holley, Carter, Weber 40 DCN and Zenith. Single-throat Solex 32 PDSIT on stock VW manifold shown for comparison.



36, 38, 40 DCN & DCN F Webers

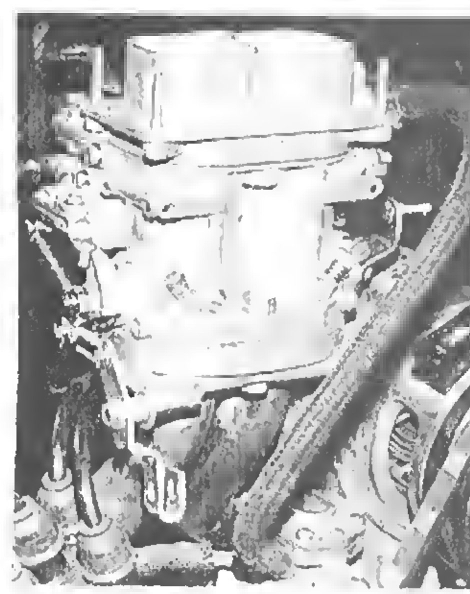
There are a lot of different models of these carbs which have been used on different cars, notably Dino 206 GT, Fiat Dino Spyder, Lancia Flavia Sports, Lancia Flaminia Supersport and Ferrari 275 GTB (six of the carbs). Expect to pay about $100 per, plus an additional $6 each for venturis and 1.35 for jets.

If you have tried to do anything with these carbs, you already know that a lot of apparently strange things happen to the supply. One day there will be one type available and the next—that model has been obsoleted by something new. In December of 1970, the 40 DCN 14 was replaced with a 40 DCNF 3 which had a four-bolt flange instead of the previous three-bolter. By 1972, the only 40 available was a 40 DCNF 12.

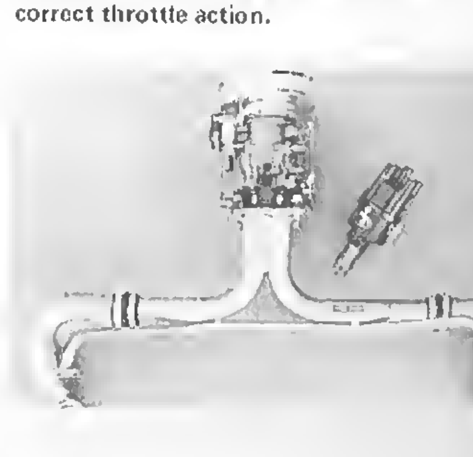
Some 40 DCN carbs are delivered with 24 mm venturis and others have 32 mm venturis. On the 24 mm 40 DCN 14's the mains are 1.30, air corrections are 2.00 and emulsion tubes are F38. The 32 mm venturi 40 DCN 14's have 1.30 mains and 1.85 airs with F33 emulsion tubes. 40 DCN 3's have 32 mm venturis, 1.30 mains, 1.70 airs and F25 emulsion tubes. There are probably other combinations, too.

If you plan to use a single 40 DCN, mill a small slot in the base like that in a Holley Bug Spray. This will help to eliminate fuel standoff when you use the carb on an isolated tube manifold to get away from mid-range flat spots—a common problem with plenum-type manifolds on any engine—whether VW or big Detroit iron. The throttle lever probably won't work in the correct direction, so a linkage will have to be built to adapt it to the VW's throttle cable.

The 24 mm venturis won't give as much HP as a box-stock Holley—at least not until the venturis and jetting are changed—costing still more $$. For a single carb, consider that Holley. In a dual-carb setup, 40 DCN's with 30 or 32 mm venturis should work as well as a pair of the DCNL's. ACE and Berg make manifolds to mount one DCN on each dual-port head. When buying these carburetors—or any others—it is extremely important to deal with a dealer or manufacturer who will help you to get straightened out with the best venturi and jet combination. Don't hesitate to ask around at the drags. Or, when you get the catalog, see whether it has useful information—or just a super sales pitch.



40 DCN Weber with 24 mm venturis provides unexciting performance, yet costs $30 more than a Holley. By the time you get one of these jetted and venturied for a single-carb application, you'll have shot the better part of $90, not including the manifold. Plate under this one is slotted to reduce fuel standoff. Note special linkage needed to get correct throttle action.



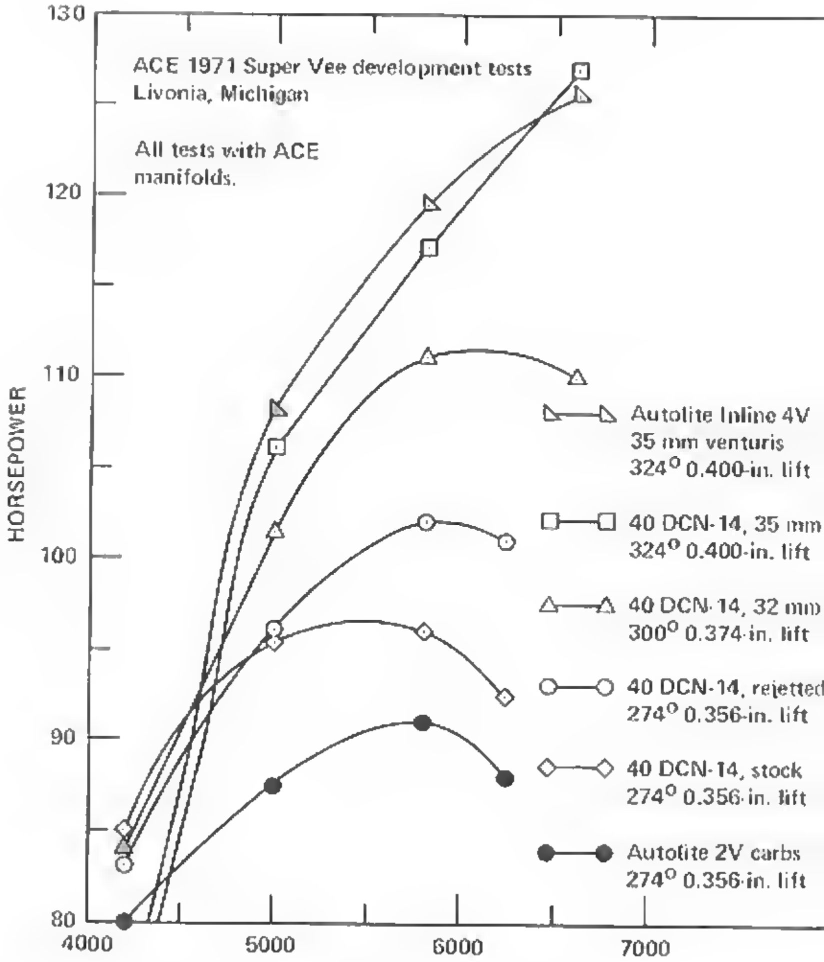
1971 VW manifold castings fit onto this Berg center section with heat riser to adapt single 2-barrel carb to the popular dual-port heads.

ULTIMATE CARBURETION: ONE VENTURI PER CYLINDER

If you are after peak performance for racing, consider using a dual-throat Holley, Solex or Weber at each dual-port head. There's no real need to consider such carburetion for the single-port head unless you've gone the limit of all-out modification with extra big flanges and so forth . . . so save your money if that's what you were thinking.

This is an impressive number of holes, but there is universal agreement among VW enthusiasts and tuners that this is the ultimate carburetion setup for dual-port headed VW's with 1500cc or larger displacement. Venturi area is increased according to the size of the venturis. Placing the carbs close to the ports insures good throttle response and improves the fuel distribution over what you'd get with a centered two-barrel carb on the dual-port heads. Because the manifolds are warmed by the hot cylinder heads, good fuel vaporization is obtained if the venturis are not too large.

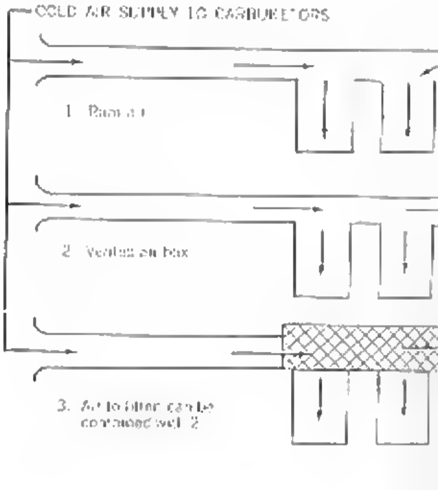
Disadvantages, some of which have already been discussed in detail, include worsened low-RPM torque and a need for more gear shifting, carburetor synchronization, expensive carb linkage, high cost, and higher fuel consumption if you use the added performance. Some of the dual kits do not allow installation of any stock air cleaners . . . which means that the air cleaners often get left off because it seems like too much trouble to fabricate special ones which will fit and work.



RAM AIR & COLD-AIR BOXES

Some would-be speed tuners have the mistaken idea that they can add a mild form of supercharging at low cost by connecting rubber hoses to their carburetor(s) from scoops on the fenders. Any apparent improvement thereby obtained is due to the engine receiving cold air—and not from any supercharging or "ramming." Ram air can provide minor HP improvement at very high speed: +1.2% at 100 MPH, +2.7% at 150 MPH, and 4.8% at 200 MPH. But, according to Colin Campbell, this small power addition also creates problems. Unless the ram air is fed to all parts of the carburetors, including the float bowls and all vents, carburetion is disturbed, especially at low speeds. In his book, "THE SPORTS CAR—ITS DESIGN & PERFORMANCE," he states that if a cold-air box is arranged to feed the carburetors, it should be designed without ram effect by allowing free flow of the air out of the box feeding the carburetor filtered intakes. Cold air will give you more improvement than ram air because 1% HP is gained for every 2°F temperature drop. Of course, this assumes that the mixture is adjusted to allow for the change in mixture density and that there is no detonation or other problems. Cold-air-box use is climate-limited because too-cold temperature will cause icing. Air scoops on the fenders or deck lid are o.k., provided they are not connected to the carburetors—but to cold-air boxes which are vented correctly.

For complete details on ram tuning intake systems, refer to Philip H. Smith's book, "THE SCIENTIFIC DESIGN OF EXHAUST & INTAKE SYSTEMS." Perhaps one of the best single articles written on the subject was by Roger Huntington in the July 1960 HOTROI Magazine, "THAT CRAZY MANIFOL July and August 1964 HOTROD Magazines had two further articles whi were written by Gordon H. Blair, Ph.D All are worth reading; however, the us of a dyno to measure the real performance of a specially constructed "tune system—either intake or exhaust— is absolutely essential.



FUEL PUMP

Use the stock pump. Look at the engines of the hot runners—either at the drags, autocrosses or off-road—and you'll see a stock pump every time. Sharp tuners save their money for more important items. All that's needed is to run an "O" drill through the phenolic block and polish the exterior of the pump push rod before installing the pump.

Why polish the rod and drill block? According to Gene Berg, erratic stopping of the engine is often traceable to a sticking fuel pump pushrod. The engine may stop and will only restart when the engine has cooled.

The stock line from the tank up front is adequately sized for everything except all-out long-distance sportscar racing where full throttle is maintained for lengthy periods of time. VW's built through 1961 may occasionally have problems due to the cork gasket in the fuel filter by the tank, so always replace this gasket if it is swelling or breaking up. 1962 and later VW's have a screen which should be kept blown out. At the back of the car, the stock neoprene hose connections to the carburetor are the best you can buy, so always replace these or make new fuel lines to the carbs out of the genuine VW hose.

If you have a drag machine, there's good reason to run a fuel pressure gage so that you can be sure that the carbs are getting what you think they are in the way of fuel supply.

Don't let any salesman try to talk you into parting with your coins for an electric pump. 'Tain't necessary!

Some VW racers do run electric pumps and I can't understand why because the gasoline in the bowls of a pair of Weber carburetors is probably enough to get the car through the quarter mile. Jeff Quick of ACE says that the 1600 pump has somewhat higher capacity than the previous pumps, providing a constant 3.5 psi at 7,000 RPM with two Weber 40 DCN's on one of his Super Vee engines.

Jeff Quick checks out a 40 DCN Weber carb which he installs in pairs on ACE-equipped Super Vee engines. One of these manifolds is on the cover of this book, complete with air horns. These are destined to become the best carb for high-performance VW's, which must use dual carburetion. The Holley Bug Spray wins in single-carb applications.

AIR DENSITY MEASUREMENTS

The ability to pull the very last foot pound of torque, the very last horsepower from a high-performance engine such as the reworked VW does not come easily or quickly. Constantly working on one basic engine in various stages of tune, under several different sets of circumstances, will help nourish the growing ability to "feel" an engine's needs for peak performance. But this "sixth-sense" or "feel" is fighting a losing battle unless you have the correct tuning tools at hand and fully understand how to use them in a workmanlike manner.

One of the most overlooked but necessary tools for tuning specifically for a short-course race—drag-race or short road course—is the air density meter. A mechanic need not have much more brain power than needed to heat his hair oil to realize that a car simply runs better on some days than on others. Taking command of this situation and doing something about it is a big kettle of fish which can be cooked by guess and by golly while someone else gets the checkered flag, or can be solved in a scientific manner with the aid of an air-density meter.

More specifically, the correctly tuned engine must be correctly jetted. Let us assume that you spent the most of one day at a local drag strip in an effort to tune the car—to "dial-in" the correct jetting. You finally arrive at the "correct" combination. This determination comes after repeated runs through the quarter mile with different combinations of jets. No matter how you keep track of the performance—you are convinced that the car is right. Push it on the trailer and go home. Don't change a thing on the car all week. Next weekend, at the same strip the car falls flat. The edge is gone. What happened?

Air density changes from hour to hour, day to day and most certainly from weekend to weekend. The power of an engine is directly related to air density. Air density is affected mainly by two factors: air temperature and barometric pressure. As barometric pressure decreases and/or ambient air temperature rises, engine horsepower falls off. Conversely, an engine will produce more brake horsepower as barometric pressure rises and/or temperature drops.

An internal-combustion engine must maintain the proper air/fuel ratio by weight NOT volume, to achieve maximum power output. The carburetion of the VW will provide this proper ratio—but only for a given air density. Thus, as air density varies, so must jetting.

Once this is understood, all a tuner needs to maintain the proper ratio of fuel/air being used by an engine is instrumentation which will measure air density, some sort of logbook to record best jetting for a given density, and an adequate number of jets to make the needed changes.

Keep in mind as you view an air-density meter that the calibrations on the dial are only to show relative differences. The standard sea level condition of 59°F with a barometric pressure of 29.92 inches of mercury is represented by 100% on the dial face. A diaphragm bellows inside the instrument

K-D air density meter is an essential tool for the serious tuner.

has a given volume of air sealed inside it. This diaphragm is caused to expand or contract by the surrounding barometric pressure and air temperature. In turn, this motion is transformed into needle movement on the dial to indicate the actual percentage of air density. Neat, you can buy one from K & D—who've been making them since the early sixties—for about $70. How to use it?

Tune the car at the race track until it runs as well as you feel it should. Record the jet size being used and take a reading from the air-density meter. Make certain that the air-density meter is placed in the shade and is allowed at least 10 minutes to stabilize. With the first reading from the meter and the jet size in the carb recorded, we now have a base line from which to make changes. The trial-and-error method of arriving at correct jet size is now history.

As an example, we'll say the car gave maximum performance (quick time) with a 1.80 jet with the meter reading 98%. Around noon the air density drops to 92%. This is a 6% drop in air density. This means that to maintain the proper air/fuel ratio, that the jet AREA should be decreased by 6%. AREA is the key word here, because AREA controls the fuel quantity which can flow through that tiny hole. Refer to the area chart which is provided with the air-density meter. Your 1.80-mm jet has an area of 0.004072 square inches. Multiply the area by the percentage of difference. 6% X 0.004072 = 0.000244. Subtract this amount from the original jet size AREA and you get 0.003828. Checking the chart again, we find that the closest area to this recorded on the chart is 0.003848, which turns out to be a 1.75-mm-diameter jet—the correct jet for use at 92% air density in this example.

Each time a change is to be made (each time the air density changes) carefully record the density, and the correct jet size for that density. This eliminates the necessity for figuring out the correct size jet to run each time. Simply refer to the log book. Check the air density meter often and change jets accordingly. After several months of this, the correct jet changes come to mind automatically—thus your speed and skill as an engine tuner increases greatly.

Some tuners calculate the jet sizes for a range of air densities—at work with their calculating machines—or with a slide rule. These are recorded in the logbook so that going up or down at the track requires merely looking at the pre-calculated table of air densities versus jet sizes. The dynamometer provides a load condition which is seldom duplicated in the car. Slightly lean jetting usually produces the best horsepower output on the dyno. For this reason, you should always run at least one step larger main jet than provided the best horsepower on the dynamometer. Otherwise, you may "fry" pistons and valves with a too-lean mixture.

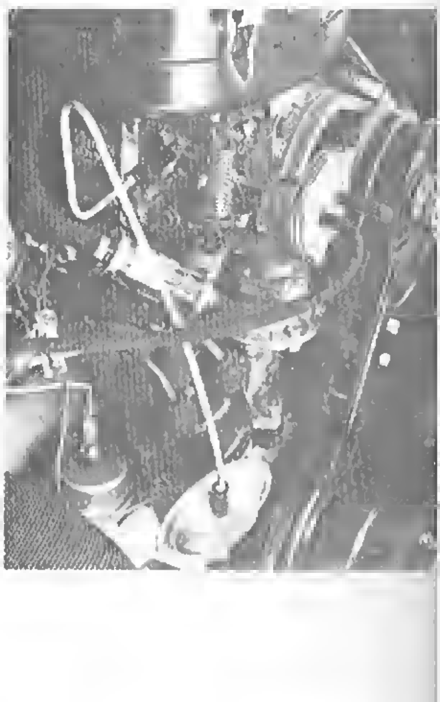
SMOG DEVICES

VW smog or anti-pollution devices are the simplest kind. There's no need to tear yours off to try for more performance, because you are not apt to find any by so doing. And, if you live in California, there are severe penalties for taking off the equipment or rendering it inoperable. This law is enforced by many road-block-type car inspections which check hundreds of cars in a day. 1963-67 VW smog device is a crankcase breather which exits into the air cleaner to recirculate crankcase fumes into the engine through the carburetor.

In August 1967, with engine H 5 000 001, an emission-control system was installed. This vacuum-controlled throttle positioner holds the throttle partially open during the overrun (when you've let off on the throttle and the car is slowing down "in gear") to feed a completely burnable mixture to the engine, even under high manifold vac[uum]. Otherwise, the engine gets an over-ric[h] mixture which can only burn partially. This is what causes backfiring in the e[x]haust system when descending a hill, [for] example. This throttle positioner red[uces] the braking which you can expect fro[m] your VW, because you cannot get full engine braking with the engine contin[uing] to be fed fuel as if it were running 17[00] RPM.

The throttle-positioning mechanism itself, does not reduce performance, b[ut] the distributor and distributor setting[s,] the carburetor and its calibration detr[act] from acceleration and cause annoying running on of the engine when it is sh[ut] off (because the carburetor is set very [lean] and the distributor is 'way retarded at idle). This distributor is an all-vacuum advance unit. This distributor-drive-ge[ar] unit is installed 30° (one tooth), coun[ter]clockwise from the position used for earlier VW's which had the slot paralle[l to] the crank pulley and with the narrow [side] of the slot towards the pulley. Static spark advance is set at TDC (0° advan[ce]

Second-design throttle-positioner for [...] smogged VW's holds throttle partially open on overrun. Time delay fast idle[s] engine for several seconds, even when [you] stop—o.k. for the *Autobahn*, perhaps, [but] terribly annoying in city traffic. Oil-pr[es]sure sender below distributor is for EM[PI] gage. See-thru fuel filter is another of that firm's niceties.



and there is 32 to 35 degrees advance in the distributor.

NOTE: Automatic-stick-shift distributors incorporate both vacuum and mechanical-advance mechanisms, as did some earlier transporter distributors.

The carburetor on desmogged-VW's is a SOLEX 30 PICT 2; different from earlier carburetors even though it bears the same number. It has smaller main jets (116 instead of 120), a larger power jet (60 instead of 50), and two vacuum outlets (one on auto-stick shifts). The jets were chosen to minimize emissions—not to maximize performance. The idle mixture has been set extremely lean with a concealed screw in the carburetor. You should probably leave this alone, especially if you live in California. Unless you experience tip-in or stumble problems as the car comes off of idle, there's no need to richen the idle mixture, but the main jet can be replaced with a larger one for performance, especially important if you change the exhaust system to an extractor-type which provides better cylinder scavenging.

The previously used vacuum-advance distributors have 22° advance (VW), which, when added to the 7.5° BTDC Static setting provides 29.5° and 32.5° total advance.

What's the net result from all this smog equipment and modification? Obviously, the first and most important result for all of us who are breathing people is that pollution is truly reduced. The engine, however, suffers from running too hot because an extreme amount of spark advance is used throughout the RPM range. For instance, plugs live about 6,000 miles as a maximum, exhaust valves burn frequently, crankcase studs pull out, and cylinder heads warp. Oil temperature is higher, so bearing life is sharply reduced. That is the small price which we now pay to get rid of pollution. 1970 VW crankcases are drastically changed from earlier models—probably to get rid of problems caused by the smog equipment. The 1970 cases, the only ones supplied by VW dealers as of 1970, are beefier around the case studs and have larger oil galleys with a relief valve at the most remote part of the oil galley. This increased flow of oil gives added cooling to reduce crankcase problems which have plagued the models with the desmogging setup.

Performance Modifications For De-Smogged VW's

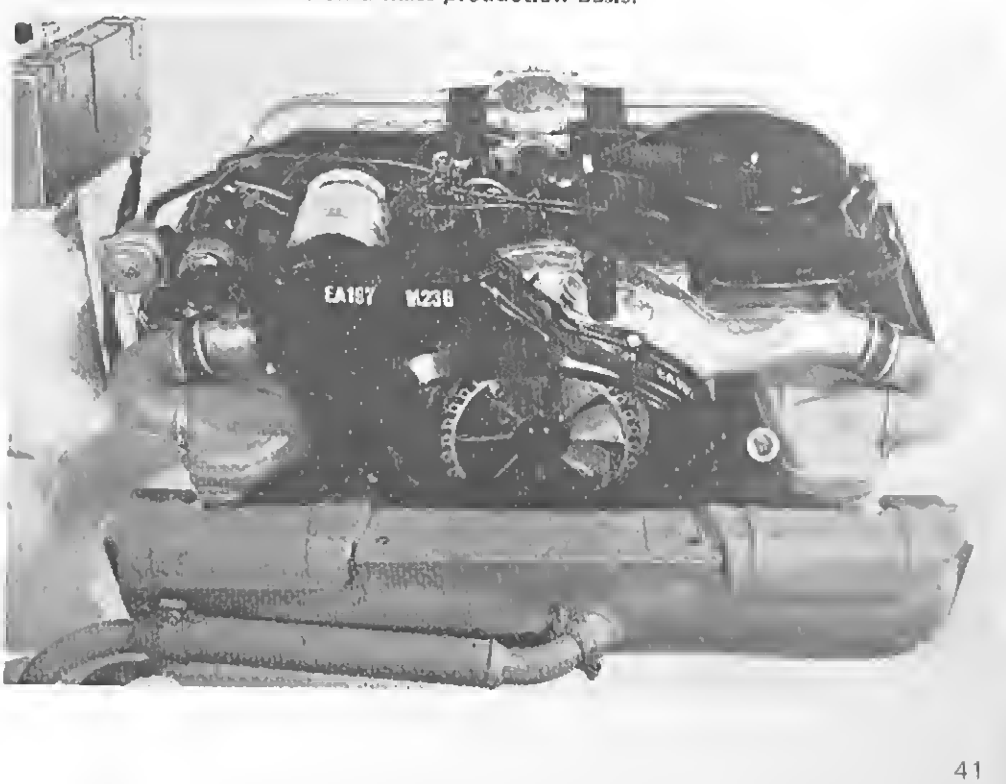
For drag race or autocross performance from desmogged VW's, you'll have to: (1) deactivate the throttle positioner by plugging the vacuum hose which actuates the positioner to make the throttle hang open on the overrun; (2) reduce the amount of advance in the distributor to 22° to 25°, (3) reset the timing so that static spark setting is 7.5° BTDC (center notch on the pulley); and (4) increase main jet to at least a 120.

FUEL INJECTION

Fuel injection is used on all 1968 and later fastback and squareback models with dual-port 1600cc engines. Dyno tests of these fuel-injected engines show that they are considerably more powerful than the factory sales literature's claim of 65 HP. The clever Germans probably decided that it was easier to build in the HP one time, rather than to make yearly changes to meet new HP claims demanded by the sales department. Anyone who has driven one of these machines will admit that the engines are "strong."

Many who purchase used injection engines for use in dune buggies or to update an older beetle are overwhelmed by the seeming complexity of the Bosch fuel-injection system. Even though the parts are expensive ($75 for the "brain box" computer on an exchange basis), the added performance and fantastic record of trouble-free performance should endear these units to those looking for the utmost performance. If you have the opportunity to use one of the fuel-injection systems, give it a try before discarding the idea, even if you have to buy missing parts.

Electronic fuel injection is a VW "first" which took the automotive industry by surprise when it was introduced in 1968 on Type III vehicles. It is now generally accepted that fuel injection will replace carburetors in the U.S. by 1975. VW was the first maker to offer it on a mass-production basis.

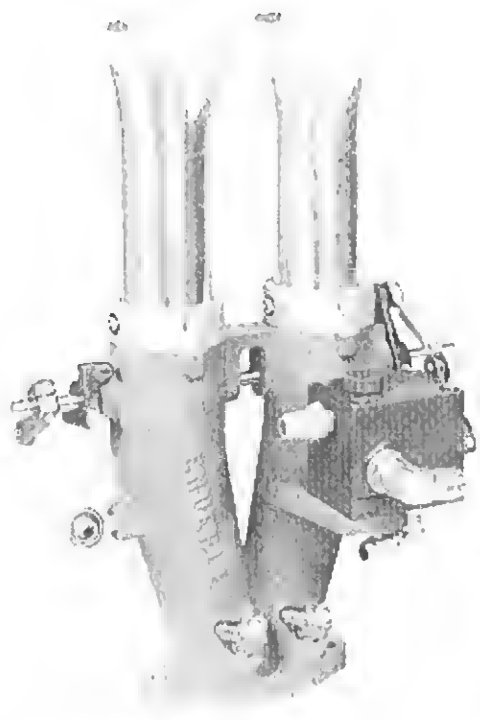


A Bosch report says that the advantages of fuel injection over carburetion include higher horsepower with the same piston displacement, improved brake specific fuel consumption, higher torque at the low-speed end, better engine response to load changes, a more uniform fuel/air ratio for all cylinders, and reduced emissions of air pollutants. That's a basketful of good things—too good to throw out.

FLAT-OUT RACING INJECTORS

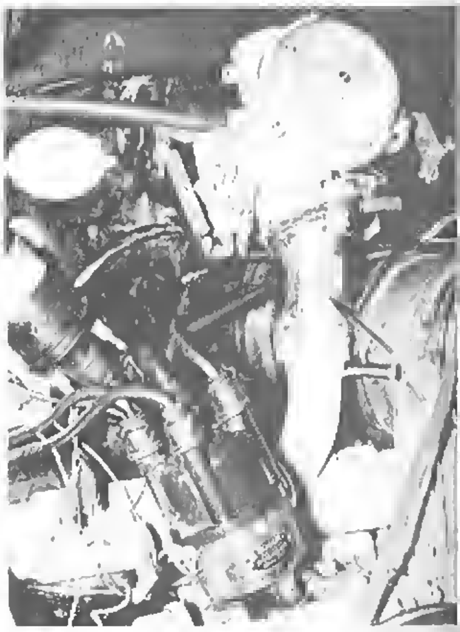
Constant-flow fuel injectors—the type pioneered by Stu Hilborn of Fuel Injection Engineering—are available for the VW for about $300 per system. Both Hilborn and Enderle Fuel Injection make the units for flat-out racing only. You shouldn't even consider using them on the street. Tuning the injectors is more of a problem than most novices would like to think and this is complicated by the "reverse jetting" required for mixture control. A jet in the return line from the mixture-control valve must be made larger for a leaner mixture—and small for a richer mixture. This type of injector should work well for VW's racing on circle tracks where the RPM's are held fairly constant—and for drag racing where the name of the game is full throttle all the way.

One thing which should be noted in passing: the Bosch-VW fuel-injection system has limited RPM capabilities. A combination of electrical and mechanical factors prevent cycling the injector solenoids at rates beyond those which will produce 6,000 RPM. Many attempts have been made to run them faster, but this cannot be done without duplicating circuitry and injectors.

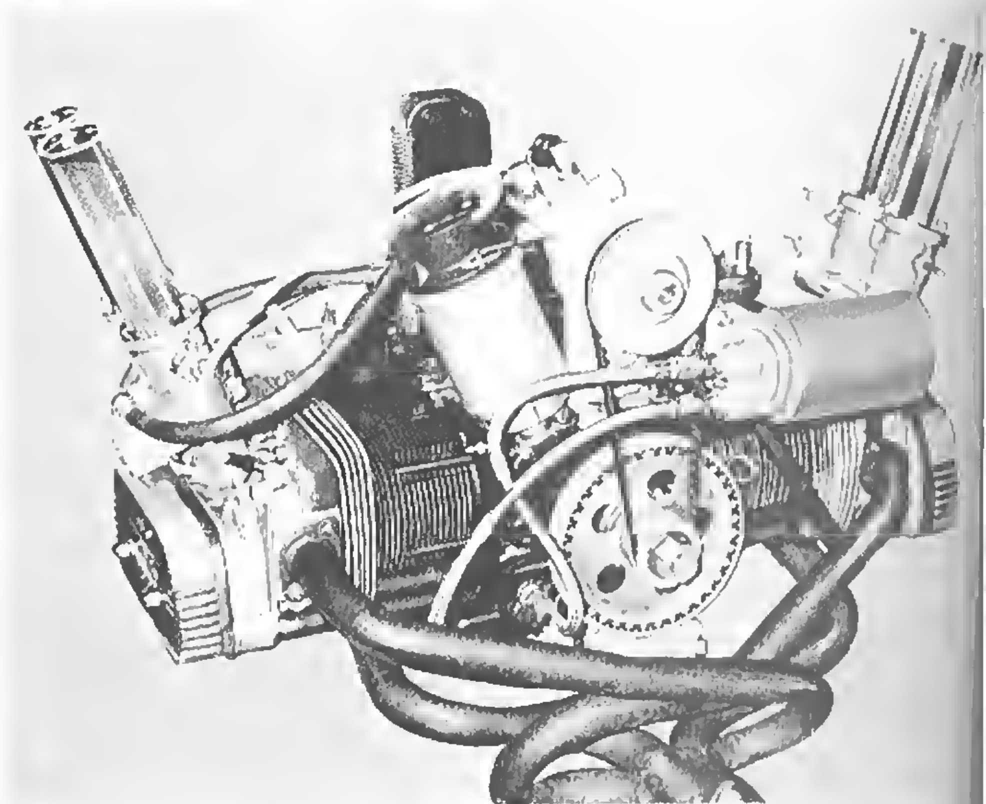


Enderle fuel injection places throttle plates just below the trumpet tubes. Black box barrel valve varies fuel return to supply tank according to size of restrictor "pill" in return line and according to throttle opening. Throttle linkage supported in Heim ball joints.

An EMPI experimental setup, Mikuni/Solex constant-depression BDS 36 carbu tor adapted to stock manifold. Carb is similar to Stromberg CD constant-depres sion carburetors widely used on Triumpl and other automobiles.



First Hilborn fuel injection for VW's appeared in January 1970. Engine here was prepared by S & S Racing.



Exhaust
. . . the cheapest HP adder

VW's exhaust through short ports directly into exhaust stacks which lead to the muffler. This excellent design allows simple machining and keeps the ports short to reduce heat transfer to the head. Exhaust is carried straight back to a muffler that incorporates an equalizing chamber with two exhaust-pipe outlets.

The stock muffler does an excellent job of noise reduction over a wide dynamic range of frequencies: 20 to 200 pulses per second from 600 RPM idle to 6000 RPM. Muffling is a complex phenomenon because the muffler must smooth the exhaust flow and reduce resonances which occur at several speeds in any system. Each of the baffles, tubes and chambers in the stock muffler is designed to attenuate or reduce the noise produced at a particular engine speed. Replacement pack-type mufflers always resonate badly at several speeds, creating considerable noise. This can be really objectionable to you and your passengers if the resonance occurs at a speed which coincides with that used for a lot of your driving. Longer mufflers are quieter—as are mufflers with a larger diameter and more internal baffling. Special systems can be built that are even quieter than stock. For instance, you could use a Corvair muffler on the end of a 4-into-1 system for the VW and have a really quiet car—at the expense of ground clearance, of course.

Why are the 2-into-2 systems so much noisier than the 4-into-1? Consider that your four-cylinder VW turning 4,000 RPM gives out with 8,000 exhaust pulses per minute, or 103 per second. This sounds smoother than an exhaust split into two two-cylinder sets, each talking at a 51-pulse-per-second rate. The lower rate is louder to everyone's ears and is heard from two separate sources. It's a cop-calling stereo system. If you couple the exhaust pipes with an equalizer tube placed ahead of the mufflers, then each side speaks more softly—and at the 103/second rate—back pressure is reduced and the apparent noise level approaches that of the stock system. Because all tests thus far give the 4-into-1 an edge on power, the use of 2-into-2 systems may soon fall out of favor, except perhaps among street buggyists who never seem to "get the word."

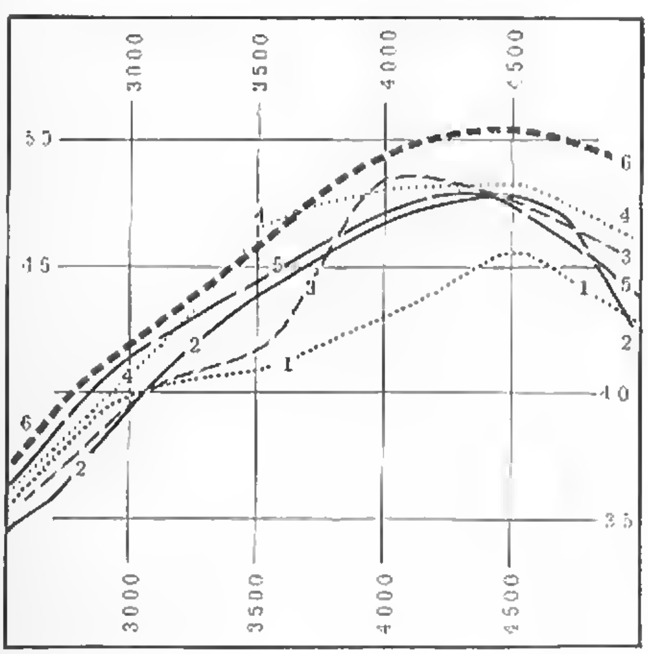
Don't regard noise lightly if you want to use your VW's full performance potentialities. A quiet exhaust system attracts much less attention than a noisy one. The same is true of carburetor-intake noise because it can be louder than the muffled exhaust under certain circumstances.

AVAILABLE SYSTEMS

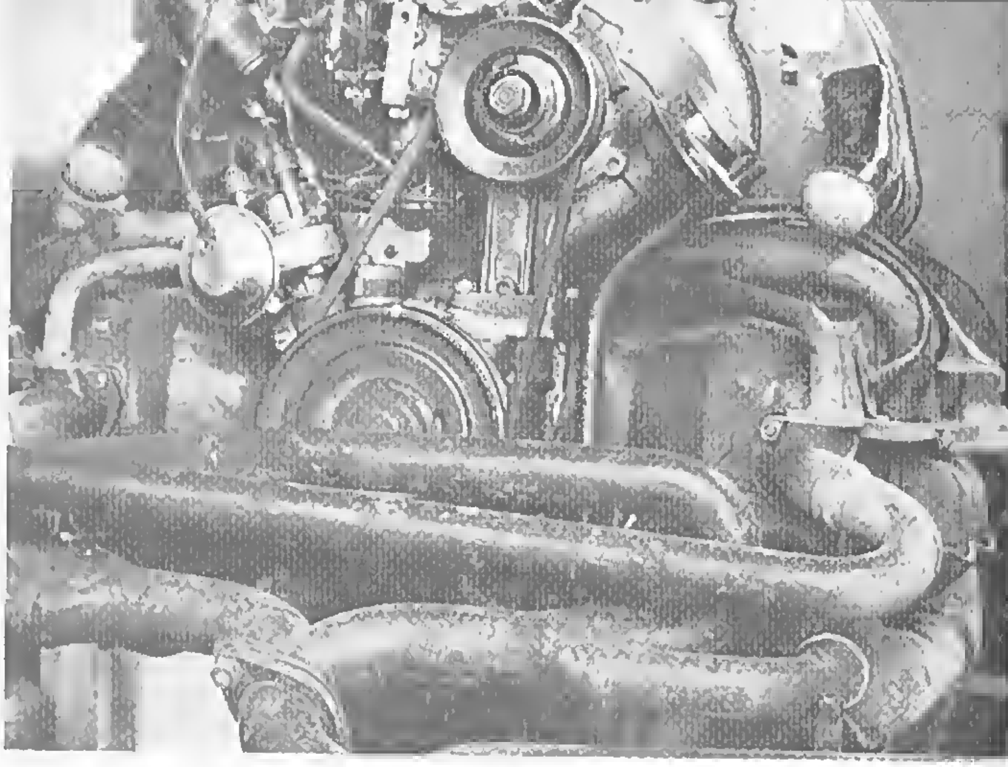
As you read in the bolt-on HP section of this book, the use of a special exhaust system can be very rewarding, adding about two to three HP to an otherwise stock 1500 cc VW engine. That's about a 6.5% improvement. When a stinger is bolted onto the outlet of a 4-into-1 system, the increase (for a stock engine) jumps to as much as five HP, or almost 11%. Most of the systems now sold for the VW have pipes which are about 40 inches long, which is a good compromise length for the available space in the back of a VW sedan. This length also works well with stock engines and with those which have added camshaft, carburetion, compression and displacement.

BUILDING A TUNED EXHAUST SYSTEM

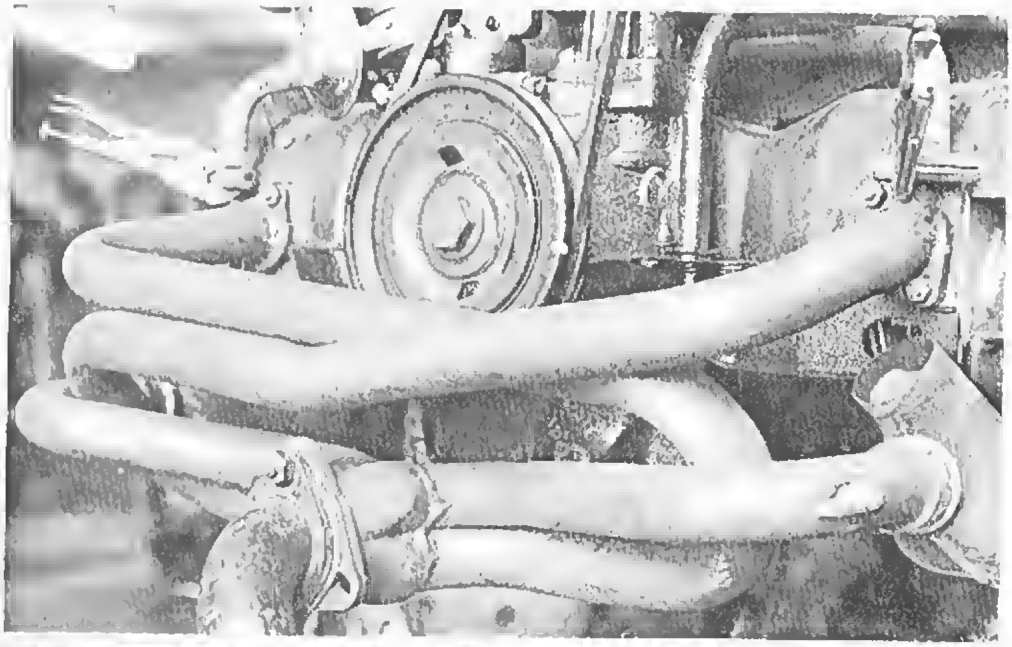
Boy, that oughta be real easy, shouldn't it? 'Fraid not, too many factors enter into the construction of a tuned exhaust system, including bore, stroke, exhaust duration, exhaust-port diameter, and the speed of gas in the system. Before attempting to build a tuned system on your own, you may want to consult a couple of good books for

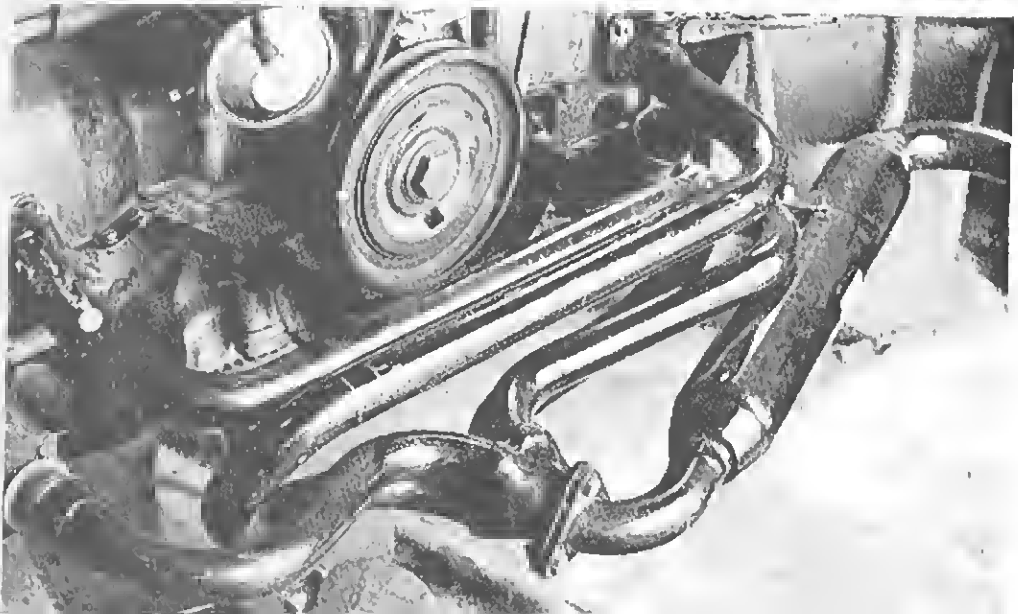


Stock mufflered system 1 was bumped up 2.5 HP by merely blocking heat riser, 2. No intake-manifold heat was used on subsequent tests. Test 3 of Mickey Thompson 2-2-1 system paired a left pipe with a right one on each side, then joined into a collector. This worked fine from 3800 to 4300, but had an awful hole below that speed: as much as 5 HP off of the best mufflered system. Andeck 4-into-1 system with 44-inch-long pipes, test 4, "gave away" some power below 3200, but was strongest mufflered system to 5000 RPM. Fourtuned 4-into-1 system, test 5, was retained for following bolt-on HP tests because I wanted to show the best-possible power at low RPM's. Stinger (exhaust megaphone) added to Fourtuned system in 6 shows how this simple bolt-on item can be worth up to 3 HP on a stock engine for enhancing drag-race performance. It's worth more than that on a hotrodded engine, of course. All tests were made with an otherwise-stock 1500 cc 1967 VW engine on a Stuska dyno.



"Extractor" exhaust systems. Top: Mickey Thompson (now Holley) paired 2's into 1 system. Center: Andeck system with 44-inch pipes. Bottom: Fourtuned has angled flange out of collector so that bend into muffler will be less severe when muffler is tucked back to clear rear underside of VW sedan.





helpful tips which will save your time money. "THE SCIENTIFIC DESIGN EXHAUST AND INTAKE SYSTEMS" Philip H. Smith and "THE SPORTS C ENGINE" by Colin Campbell have a l of helpful information that the seriou tuner will enjoy reading and find prof able in his quest for more speed and power.

Using one of the formulas from Smith's book, a broad-range tuned sys for your 1600 cc VW would require 1-1/4" to 1-1/2" diameter pipes 53.6 inches long from each cylinder into a 366 cubic-inch collector box. It woul then connect to the muffler through a inch-long pipe of at least 50% larger cr sectional area than the individual head Or, if you installed 35 mm exhaust val the individual headers would need to b mere 42.5 inches long. But, if you installed the bigger exhaust valves toge with a 300^{0} duration camshaft, the pi lengths would need to be 56 inches. Where could you fit such a system into your VW? It would not only require a nightmarish array of pipes criss-crossin and curling under and alongside of the engine—you'd also reduce the ground clearance which is already too small. O course, you might mount the engine ahead of the axle as is done by the Formula racers.

From these details, it woul appear that the area currently being neglected in the development of tuned exhaust systems for the VW is that of t collector box. Collectors on all of the systems shown in this book are so minimal in size as to be almost non-existent. This is an area which VW tune need to research more thoroughly for extra power over a broader RPM range.

On the other hand, straight stacks are tuned for particular RPM. They are measured fro the valve seat to the end of the stack. A curve in Colin Campbell's book provides these dimensions:

8000 RPM	26 inches	5000 RPM	40 inch
7000 RPM	29 inches	4000 RPM	50 inche
6000 RPM	34 inches		

Straight stacks, per se, are very "peaky." That is to say that they may provide a big power boost at the tuned RPM—but they also detract from performance at all

other engine speeds. Formula Vee racing rules once required straight stack but now allow other systems which give a broader power range.

Comparison tests of 38-inch-long individual straight pipes on a Super Vee engine showed equal power to the 4-into-1 Fourtuned competition system (as shown on cover of book), but 4-into-1 was 7.2 HP stronger at 3,000 RPM. This 14.5% improvement means lots more acceleration in any situation or corner which bogs the engine below the RPM for which individual stacks are tuned. Every builder that I talked to reported that this was the case. At the time this book went to press, the 4-into-1 system was definitely the "hot setup" for VW hotrodding.

OPEN EXHAUST "STINGERS"

Stingers are quite popular among the drag racers. If these are installed on a 4-into-1 system, instead of a muffler, there will usually be an increase in HP through most of the RPM range. You can see from the various curves throughout this book that stingers (megaphones) do add HP.

However, if you merely remove the muffler without bolting some kind of an extension onto the 4-into-1 system, bottom-end performance will definitely suffer.

EXHAUST CHANGES REQUIRE TUNING

Any time that you change the engine so that it can breathe more freely, carburetion and ignition-timing changes will help you to get even better performance. Typically, carburetor jets must be enlarged to richen the mixture slightly at the same time.

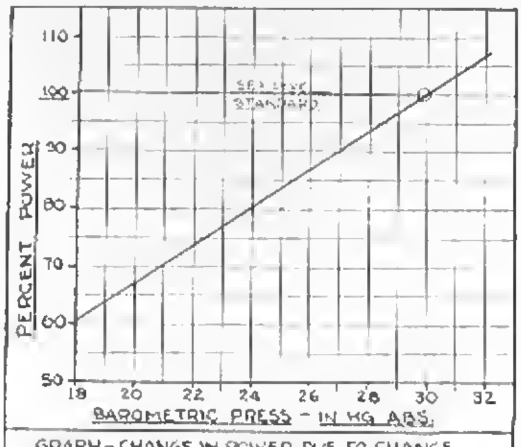
EXHAUST SYSTEM APPEARANCE

Exhaust systems can look pretty grubby and it's only a simple chore to keep them looking young. You can keep your system concours clean and rust-free by applying Sperex VHT enamel to the pipes, muffler and other parts. The parts will look best if you grind off any ugly welds and sand-blast the whole affair before painting. VHT is the paint which you've seen everywhere on all sorts of race cars and boats. It's available in black, white and a wide array of other colors.

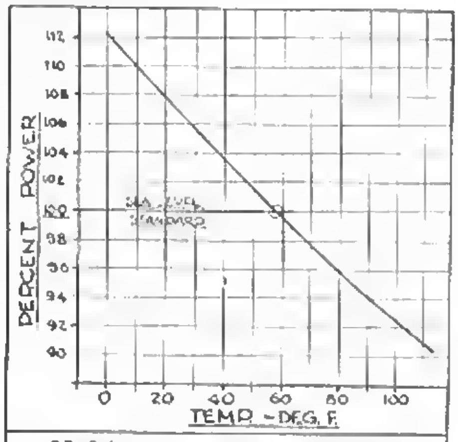
Any kind of a straight pipe is a help for drag racing or top speed, but a megaphone "stinger" works better in most cases. Narrow tires break loose at the start so engine doesn't bog down so badly.

Propped-open engine lid secured by pins is standard for drag-racing machines. Dual megaphones are interesting but we weren't able to test their efficiency on a dyno.

K-D charts show power changes due to changes in temperature and barometric pressure. Refer to Air Density Meter discussion in carburetion chapter, page 39.



GRAPH – CHANGE IN POWER DUE TO CHANGE OF BAROMETRIC PRESSURE



GRAPH – CHANGE IN POWER DUE TO CHANGE OF TEMPERATURE

Cylinder heads

both single- and dual-ports work much better when ported and seated correctly

A major stumbling block in the VW's performance path is provided by the cylinder-head design. Small valves, tiny exhaust ports and combustion-chamber faults add up to impressive restrictions in air-pumping capabilities. Even so, the construction of these heads permits extensive modifications to provide drastic pumping-capability improvements. As much as 10 HP can be added to stock engines—even more to hopped-up ones—solely through head modifications.

Simple modifications consist of raising the compression, eliminating sharp edges from the combustion chambers and valves, and setting the deck height (clearance) for best turbulence in the chambers for more even burning of the mixture and reducing the tendency to detonate. All chambers must be made to have the same exact volume and valve seating must be given particular attention. Bigger valves can be installed and the intake and exhaust ports reshaped—but indiscriminate reworking in these areas must be avoided because it is all too easy to make beautiful ports which will flow less air than the stock ones. Polishing the valve heads and combustion-chamber surfaces—as well as the piston crowns—reduces the heat loss to these components, thereby improving power output. Polishing provides a secondary benefit by making carbon removal easier when the engine is taken apart for cleaning or a valve job.

Cylinder-head reworking is essential to realize the full potential of the VW. If you have obtained the idea that head work of even the "simple" variety is really a lot of hard work, you are 100% correct. VW cylinder-head reworking—or any VW work for that matter—cannot be given to just any "schlock-shop" mechanic if performance and reliability are required. A complete understanding and appreciation of what is being done must be had by the mechanic and the machinist who are doing the work. Attention to seemingly trivial tiny details is an absolute must!

STOCK HEAD DESCRIPTION

Two opposing and identical cast-aluminum cylinder heads incorporate cooling fins and contain wedge-shaped combustion chambers. Valves are actuated by pushrods through ratio rocker arms. Sintered steel-alloy valve seats are shrink-fitted into the head. Exhaust ports are short for minimal heat transfer to the cylinder head. Thick exhaust-port walls promote heat flow from the valve seat to cooling fins on the outer port wall. Wide valve spacing gives a tunnel for cooling air to pass between the intake and exhaust ports. Thick sections over the chamber and surrounding the cylinder-bore spigots give rapid heat transfer into the fins. Guides are aluminum bronze in all models for best heat removal.

The cylinder head incorporates half of the rocker-arm and valve-spring chamber. A stamped-steel cover provides the other half and closes the chamber so that oil cannot leak out. Pushrods are hollow to supply oil to the rocker arms. Oil drains through the pushrod tubes into the sump.

VW's ability to use higher-than-stock compression ratios is seriously limited by a large clearance (typically 0.070-inch) between the combustion chamber's flat section and the top of the piston. Reducing this "deck" clearance provides improved "squish" or "quench" as originally discovered by Ricardo in 1922. By assembling the engine so that the flat portion of the head is separated from the piston crown by only 0.040 to 0.050 inch at TDC, squish is improved to increase turbulence. Increased turbulence insures reasonably complete combustion of the mixture because complete combustion cannot occur at very high RPM unless the mixture is in a state of violent agitation. The cooling effect of the piston crown and flat surface of the head combine to "quench" any "wild burning" which might start in this area farthest away from the plug—thereby helping to eliminate detonation.

When squish or quench is removed from a cylinder head—or is not available (as in the case of hemispherical heads such as on Chrysler V-8's imported sports/racing cars and many motorcycles) —the angle of the intake must provide swirl turbulence to promote complete combustion—and the spark plug must be centrally located so that no area of the combustion chamber is very far from the plug.

Inclined valves have long been used in high-performance engines so that ports can enter the cylinder at favorable angles, exhaust ports can be kept short and a larger segment of the valve perimeter can be unshrouded as the valve opens. Most U.S.-made OHV engines use inclined valves, and the location of the camshaft in the center of a V-8 block allows inclining the valves so that the intake port can take a very direct approach to the cylinder. VW's valves are inclined at 9-1/2° to the cylinder centerline—in a direction which allows a more compact design, construction with a lesser amount of metal, and manufacturing simplicity . . . *not performance.* The VW's intake ports come in at a very acute angle, even on the heads with the slanted intake ports (which provide a more favorable entry path for the incoming mixture) and there's just not much that can be done about it. The minor inclination tends to unshroud one side of the intake valve for better air flow.

The exhaust-valve inclination also unshrouds one side of the exhaust valve as it opens.

Engines such as the 396/427/454 Chevrolets incline the valves in two directions so that the valves open to unshroud a much larger portion of the valve perimeter for improved air flow. Such inclination also allows much more favorable port design from the standpoint of entry and exit angles, port length and so forth.

DESCRIPTION OF HEAD TYPES

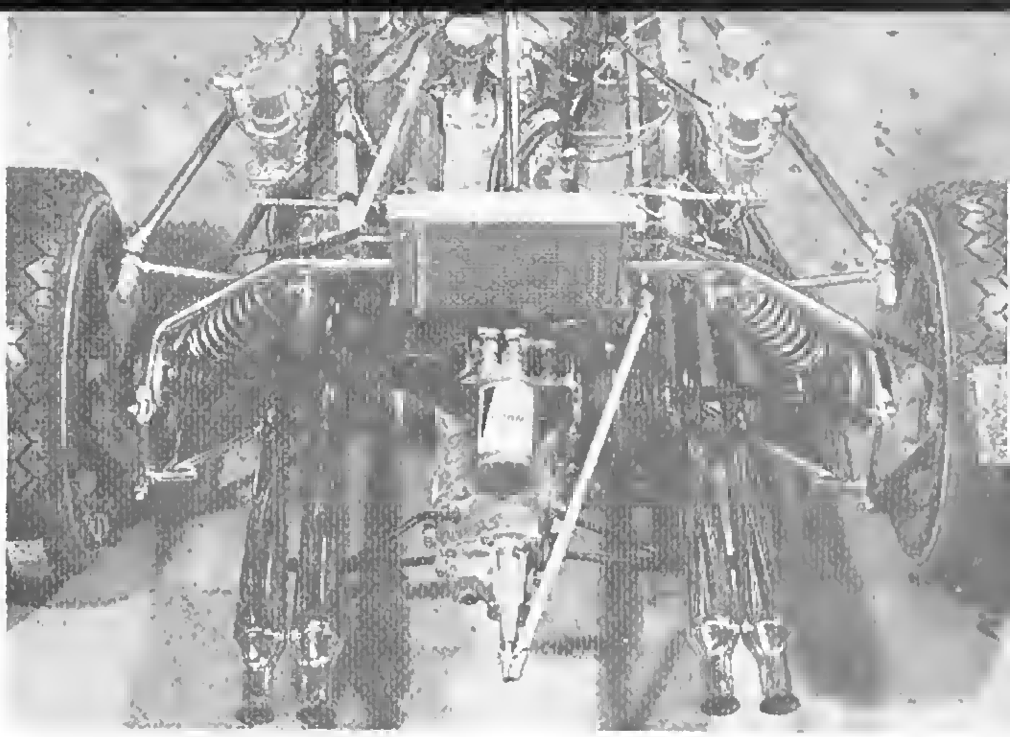
Let's look at three basic styles of heads. From the long list of part numbers which have been used, you might get the idea that there were a lot of different heads, but most of the part number changes have been due to modifications which we don't need to be concerned with in this book. Bill Walters, Parts Expert at Chick Iverson VW in Newport Beach, California, was most helpful in providing the following information on which heads have been used on what engines.

First is the 40 HP (34 HP DIN) head with "straight" intake ports. The intake manifold joins the head at a right angle to the cylinders. These are used on VW 1200 1959-62 transporters and 1961-65 beetles through engine 9 205 699. It's been supplied as 113101 351 in versions A through F.

With the introduction of the 50 HP (42 HP DIN) 1500cc engines as options in 1962 busses, intake ports were slanted towards the cylinders at a 20° angle. Fastback, notchback and squareback 1500 engines got this head design in 1965 and beetles began using it in 1966 with the introduction of the 1300 50 HP (40 HP DIN). This same basic design was continued through 1970 models, including 1500 and 1600 cc engines. You'll see these heads with P/N's 211 101 351A, 113 101 353B, 311 101 353 and 311 101 353A.

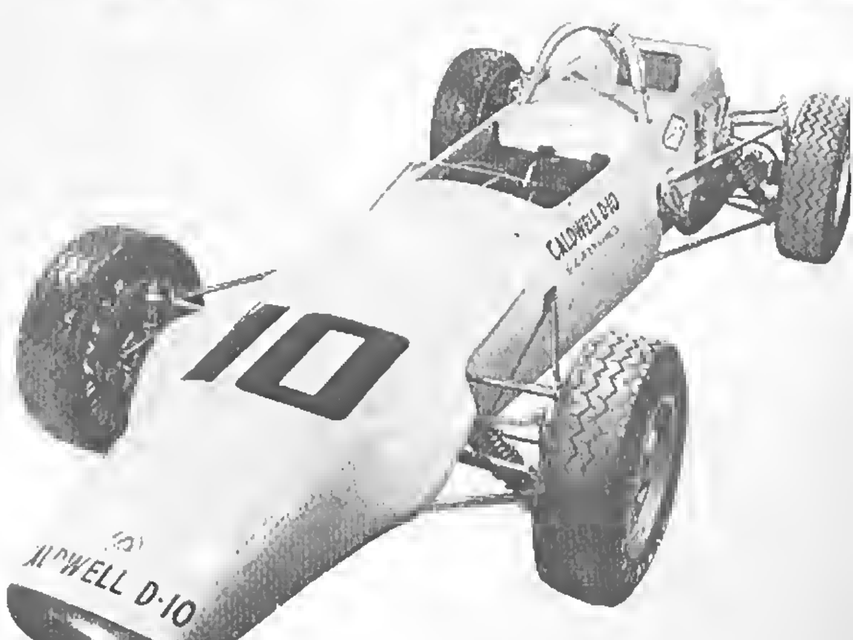
Dual-port heads are found on 1600's starting with 1967 models, but only on fastbacks, notchbacks and squarebacks. In 1971, all VW's (except 411's) were equipped with these dual-port heads. Part 311 101 353A or D tells you that you have found VW's best.

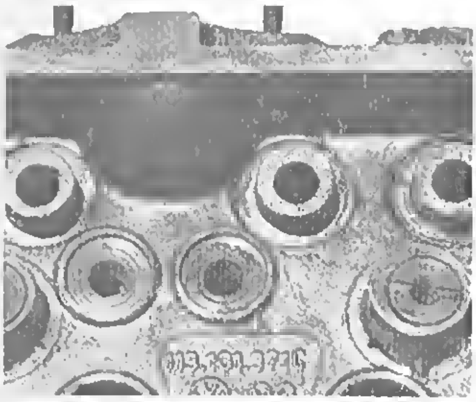
Any of the VW cylinder heads can be equipped with larger seats to allow use with larger intake and exhaust valves. The heads can be flycut to reduce the chamber



Rear of Autodynamics D10 Super Vee showing fiberglass shrouds on engine, remotely located oil cooler and filter. Carburetors are Weber 48IDA's sleeved down to required 40 mm maximum throttle bore.

Minilite wheels at rear of Autodynamics Super Vee mount 5.25/8.10 - 13 Goodyear Sports Car Special Tires.





40 HP head repaired with screw-in or pull-through rocker-stud repair kit. Such repairs are only needed when a leak develops where the stud passes through the rocker-box floor. Replacement heads from VW eliminate the problem.

volume and raise compression—as separately described in this chapter. And, the 1300/1500/1600 heads can be bored out to accept big-bore cylinders.

1961-64 113 101 351A, B, C heads for VW 1200 have 31.5 mm intake and 30 mm exhaust valves. VW advised a universal valve setting of 0.012" hot or cold on both intake and exhaust (subsequently revised to 0.008"). This cylinder head and all 40 HP heads through version "C" have had problems with rocker-arm studs, requiring various repair kits, etc. These long studs pass through the floor of the rocker box and screw into the head near the combustion chamber. Vibration wears away the aluminum where the studs extend through the rocker box, causing oil leaks. The studs often break. Repair kits stop oil leakage at the rocker box floor but cannot eliminate cracks between the plug boss and valve seats . . . which is the worst trouble with these heads. In the "C" version, combustion chambers were changed and the intake ports were enlarged.

1965 113 101 351D & E heads (from engine 9 205 700) were the first really reliable heads for the 1200 cc 40 HP engine. They returned to the 0.004" intake and exhaust valve adjustment—on a cold engine. Square-block rocker-shaft supports were again used, an additional cooling fin was tacked on, the rocker-box floor beefed up under the rocker stands and the combustion chamber changed by opening it up around the spark plug and intake valve so that it is similar to the 1300 and 1500 engines. These are excellent heads and if there are no cracks in a set of these, they are more desirable than the universal replacement heads for the 40 HP engine series (discussed in following paragraph) because they are stronger and because they cool better. The beefier construction and added fin on these heads requires the use of 5/8-inch longer studs, P/N N14 502 1, upper; N14 506 1, lower.

40 HP Universal Replacement Head 113 101 351F is similar to the D or E heads except that it has one less fin, a slightly "less beefy" floor under the rocker stands and installs on pre-1965 40 HP engines without requiring longer studs or pushrods. It uses square-block rocker-shaft stands and a cold-engine 0.004-inch valve adjustment.

1300 VW 1966 beetle heads, 113 101 353B have 33 mm intake and 30 mm exhaust valves. Intake ports which slant toward the cylinder look just like those on 1500 heads, except that the 1300's are smaller. So, the hot-tip trick is to open the heads up to match a 1500 intake manifold which has a larger diameter—and produces more HP. These performance-boosting manifolds are part numbers 211 129 701 or 113 129 701. You'll find the number on the center part of the manifold.

1961 fastback/squareback/notchback Variant engines were equipped with what was essentially a 40 HP head: straight-in intake ports, rocker-stud problems—and 35.5 mm intakes and 32 mm exhaust valves. The existence of these heads—P/N 311 101 351C, used through engine 65 745 of August 1962—was not fully realized by VW-ers in the U.S. because only a few of these cars were imported by individuals. VW hotrodding was still pretty much unheard of then, so the word did not get out with the great rapidity we see today. Editors of automotive performance magazines couldn't have cared less about anything VW was up to. Things have changed.

1962-65 transporter 1500 engines have heads with slanted intake ports, 31.5 mm intakes and 30 mm exhaust valves. Th head openings fit 1500/1600 cylinders, course. Head P/N's are 211 101 351A engine 710 799, and 211 101 353 from engine 710 800 to July 1967. These he have the same rocker-stud problems as 40 HP heads previously discussed.

1963 fastback/squareback/notchback Variant 1500 engines 65 746 to 672 69 (Aug. 62 - Sept. 64) used a head with slanted intake ports, P/N 311 101 351B It is similar to the 1300 head.

1964-66 fastback/squareback/notchbac Variant engines have an "S" series engi with "pop-up" high-compression piston These use head 311 101 353 (supersede by an "A" suffix) with 35.5 mm intake and 32 mm exhaust valves. By this tim VW tuners were catching on to the fact that VW was making big-valve heads. These are the 53 HP (44 HP DIN) and 57 HP (47 HP DIN) engines.

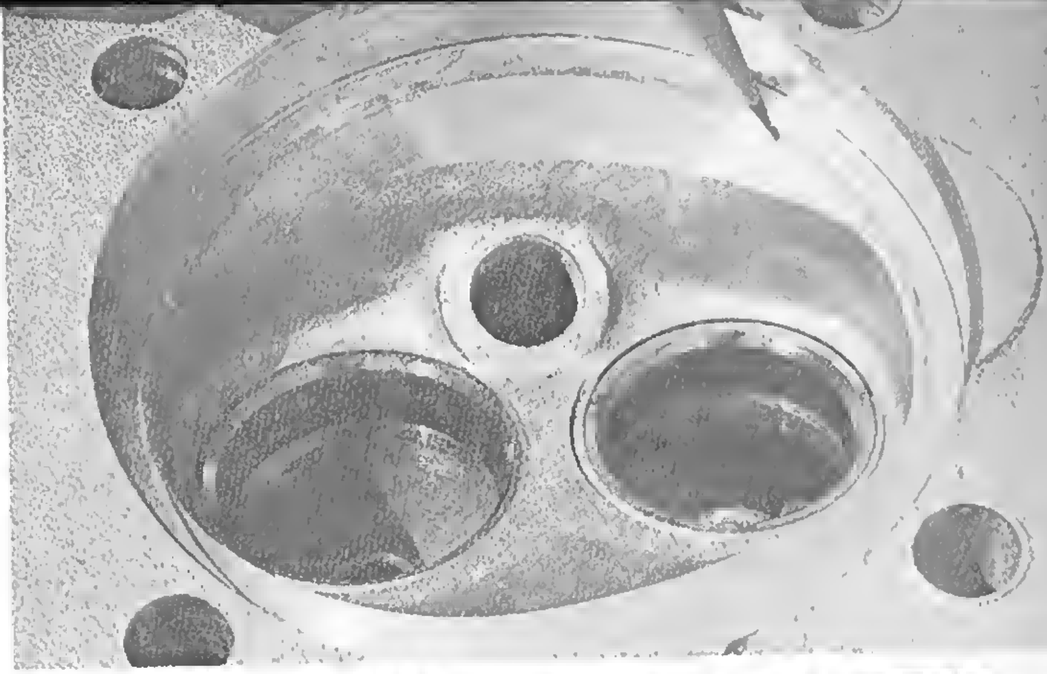
1500 and 1600 VW "single-port" heads 1967-70 beetles, 1966-70 busses and transporters, and 1965-67 fastbacks and squarebacks use the 311 101 353A hea with 35.5 mm intake valves, 32 mm exhausts and larger intake ports where the intake manifold bolts on at a 20^{o} angle. The heads are found on sedan 53 HP 1500 engines and on sedan 57 H 1600 engines, as well as 53 HP 1500 cc transporter engines from 710 800 on, 1968-70 57 HP 1600 cc transporter engines, and on squareback, fastback an notchbacks from engine 672 698 to T 0 244 543.

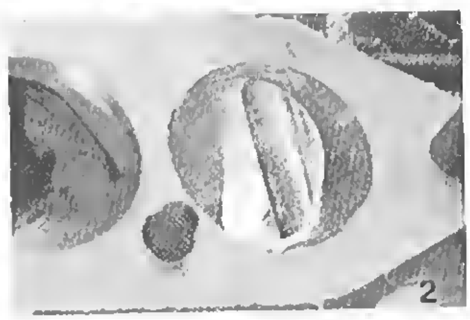
This head is used through the 1970 model bugs, busses and transporte It has stout supports for the square-bloc rocker shaft holders. These heads fit 1600 VW cylinders without modificatio The chamber volumes in these heads are supposed to be 48 to 50 cc's, but may b even larger because running changes hav been made in production to improve power output. The chamber has been changed in the spark plug area and along the edge of the quench area. This edge started out relatively straight (almost parallel with the cylinder) in 1966 and has been "rolled back" as the years have passed.

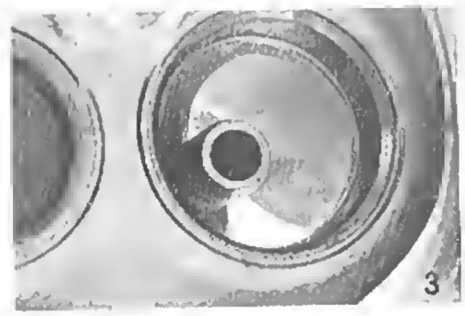
1600 VW "dual-port" heads 1968-70 fastback, squareback, notchback "Variant" engines have dual-port heads and 1600 cc displacement. All 1971 VW's have these heads. "Dual-port" means two intake ports for each cylinder head—one intake port for each cylinder. Individual intake and exhaust porting is generally assumed to be the ultimate configuration for high performance. Intakes are 35.5 mm and exhausts are 32 mm. These heads, P/N 311 101 355D, cost about $45 each at the VW store. Intake-port area on these heads can be vastly enlarged by the "square-port" technique developed by Gene Berg. These are "the" heads to use for all-out high-performance VW engines, especially where high RPM's are required from bored and stroked engines. The heads are on squareback, fastback and notchback 1967 dual-carb engines, 1968-71 fuel-injection engines, and on 1971 single-carb engines.

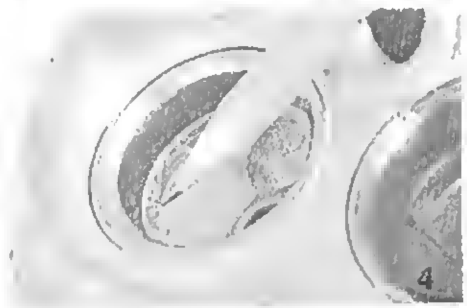
1971 exhaust valves have chrome-plated stems for better wear resistance but for a different reason than you might imagine. These allow using non-leaded gasoline because gas without lead fantastically increases valve-stem and seat wear. Don't rush to install the chrome-plated valves in a high-performance engine because chrome is a heat barrier. It slows the transfer of heat from the valve stem into the valve guide, thereby causing the valve to run even hotter. Lead, although undeniably a culprit in the pollution problem, is a fantastic lubricant. Ford Motor Company is recommending that all new or rebuilt engines should have two tankfuls of leaded gasoline before switching to a non-leaded gasoline. This coats the valves with enough lead to provide some protection against wear.

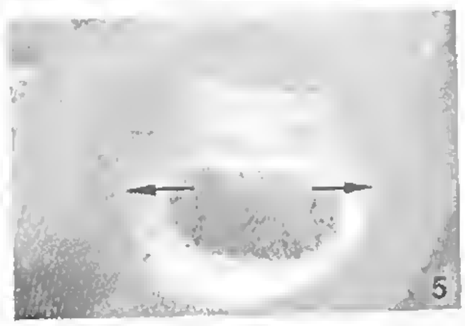
1971 cylinder heads are quite a bit different from the previous 1600 dual-port heads. The combustion chamber has a 0.055-inch (1.5 mm) step or counterbored section as shown in the accompanying photos. This step is part of VW's work in reducing pollution. However, step increases the distance between the cylinder head's flat surface and the top of the piston (deck clearance)—which reduces performance. The step can be taken out when flycutting the heads. The heads show obvious attention to air-flow improvement with no intake-guide boss, and exhaust ports which widen on each side of the guide boss. The intake



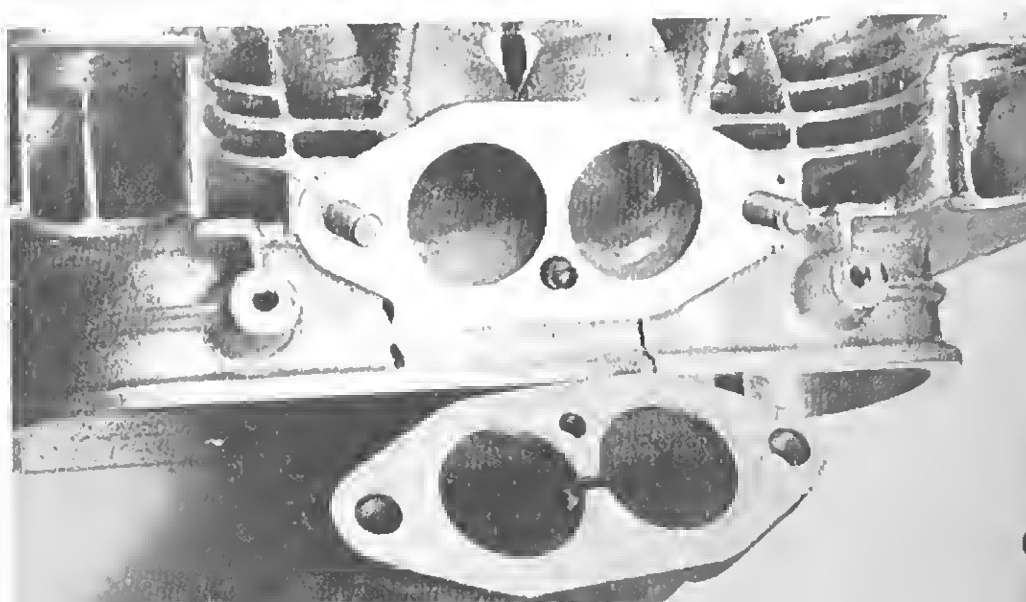








1 - 1971 head has 0.055-inch step which must be removed to regain squish or quench for high-performance applications. 2 & 3 - Stock intake port has no guide boss, thereby improving flow. 4 - Sharp edge under exhaust seat on port side must be rounded off to improve flow as described in air-flow section of this chapter. 5 - Stock exhaust port widens at each side of the guide boss for improved flow. Guide boss can be thinned during porting but must not be removed entirely. See air-flow section for details. 6 - Dowel locates intake manifold casting on head flange.



Valve Sizes (mm)

	Intake	Exhaust
* 36 HP 1100 VW	30	28
37.5 HP 1200 VW	31.5	30
40 HP 1200 VW	31.5	30
41.5 HP 1200 VW	31.5	30
50 HP 1300 VW	33	30
1500 VW (early) Bus	31.5	30
1500 VW	35.5	32 **
1600 VW	35.5	32

* 36 HP engines had 7 mm valve stems (0.273 inch); all other engines have 8 mm stems (0.313 inch).

** Some early squareback and notchback 1500's had 31 mm exhausts.

Simple angle-iron stands with welded-on studs simplify valve-seating work.

manifolds are "pegged" with a dowel so that the manifolds will go on the same way each time. As the intake manifolds are about 0.035 inch smaller inside diameter than the flange at the head, there is definitely need for matching the manifolds to the heads. Because VW has already started your porting for you, get these heads if you are going to be changing to dual-ports. P/N 113 101 355A sells for about $41 each, without valves, springs or retainers.

TOOLS FOR HEAD WORK

Even simple modifications to the VW head appear somewhat involved when all of the details are considered. The following tools are required: valve-facing and valve-seating equipment, die grinder or flexible shaft tool or 1/4-inch drill, piloted cutter to open the valve-spring seat diameter and to reduce the diameter of the valve-guide boss. Access to a milling machine with a competent machinist to turn its cranks and cutters is also necessary—or you'll need a head-flycutting tool with attached drill press.

You'll also need a fine wire brush such as Kent-Moore's J-8358 (about $4.00), a dial indicator with suitable holding equipment, a step drill and drift for valve-guide removal and installation, and a valve-spring compressor. Whether you are buying valve-seat tools or having your seats done by a machine shop, make absolutely sure that the person doing the job uses solid valve seating pilots for the seating stones—not expandable pilots! And, if you really want to be sure that the seat job you are doing—or getting—is really of top quality, you should use a seat dial indicator to make sure that the seats do not run out more than 0.002-inch. No machinist worth his salt will attempt to apply the term "precision" to his valve jobs unless he has one of these dial indicators in his tool box and uses it religiously on every seat.

CLEANING & INSPECTING THE HEADS

First, the heads must be disassembled and completely cleaned. Removing carbon from the combustion chambers may take time and care, but it's essential. Although a wire brush in a drill motor is often recommended, it must be a fine wire brush as mentioned in the preceding paragraph. Best results are obtained by leaving a section of the cylinder in place to protect the all-important sealing surface—and using an old set of valves to protect the seats. If the head is to be flycut and new seats to be ground anyway—this is not a problem, of course.

Another method of removing carbon deposits—or at least loosening their hold on the chamber surfaces so that they will come out easier—is soaking the heads in a vat or pail of carburetor cleaner which you'll always need for working on a VW engine anyway. Overnight soaking of the heads seems to loosen the carbon deposits so that they can almost be wiped away with a rag. Or, carbon deposits can be removed by blasting with glass beads or walnut hulls. Large aircraft maintenance shops have such equipment. The nicest thing about using glass beads or walnut hulls is that these techniques do not remove metal and therefore no masking machined sealing surfaces is required . . . but such masking is essential if sandblasting is used because it erodes away th metal. Clean the valves at the same time by glass blasting or walnut hulls *(not by sandblasting)*.

You may wonder why I go int all of these details about cleaning the heads when the project seems so very simple on the face of it. Thorough clean ing is important because it can help prevent you wasting a lot of time and effort on a head which should be junked After you have cleaned all of the carbon away, inspect the cylinder heads for damage. Inspect the valve seats for crack either in the seats themselves or in the head metal between the seats . . . and be tween the seats and the spark plug bosse Also check inside of the exhaust ports fo cracks or holes.

If your examination shows any crac in the aluminum, heave a big sigh, grab that head and throw it in the nearest trash barrel before you spend another minute on it. Cracked seats can be repaired, but you'll want to determine whether you are going to install larger valves before replacing any valve seats. Stock-size seats are replaceable, too.

MEASURING GUIDE WEAR

After disassem bly and cleaning, the valve guides should be checked for wear. Measure valve-sten to-guide clearance by clamping a dial ind cator on one side of the cylinder-head rocker-cover-gasket rail. The indicator stem must contact the valve stem just above the guide. With the valve head dropped about 1/16-inch off of the valve seat, wiggle the stem of the valve from side to side, using light pressure to get a clearance reading. New-guide tolerance i 0.001-inch to 0.0027-inch and old guide should not exceed 0.0065-inch on intake or exhaust. Worn guides must be replace

If you'r planning to stick with stock-size valves and you uncover one or more cracked seats *and* worn guides, you may want to scrap that head and buy a new one. The dollars required for fixing the old head may come out pretty near equal to a new head—especially if someone else is doing the work.

REPLACING GUIDES

Before removing guides, check whether the camshaft that you will be using requires special or dual valve springs. If dual valve springs are to be used, the guide boss must be turned down to 0.670-inch outside diameter to clear the inner spring. Similarly, if any valve-spring shims are to be installed, this modification of the valve-guide bosses is essential to accept the shims. Gene Berg makes a cutter tool for turning the o.d. of the guide. This cutter pilots in the guide. If larger-than-stock outer springs are to be used, it can also be used to enlarge and flatten the spring seat in the head.

Replacing guides is easy to do, but there are few tricks which the old masters use to make the job simpler and less apt to cause damage to the head. Because the guides are an interference fit in the cylinder head, when you drive out the guide it is possible to broach the hole oversize because the aluminum bronze can galt and tear at the aluminum as it is driven out. Or, the guide may swell at the middle and become almost impossible to remove.

Pushing the guides out of the heads also causes the end of the guide to swell or expand so that this too broaches the hole as the enlarged driven end passes through the head. To prevent this, the answer to this problem is a step drill which "cores" the valve guide to relieve wall tension so that the guide can be easily pushed out, especially if you heat the head first. They are available from Baum Tools for both 7mm and 8mm guides. Some of the VW performance houses stock them. Don't install the new guides until after you've worked on the intake or exhaust ports. This avoids damaging the exterior surface of a new guide where it projects into the port and makes more room for the tools you are using.

When you use the coring drill, stop when you are 1/4 inch from the end of the guide so that a step is left for your drift to push against.

To remove guides without a coring drill, tap the spring end of each guide with a 3/8-16 USS tap—to a depth of about 3/4 inch. Insert a 3/8 capscrew in the guide. From the chamber side of the guide, insert a drift so that its end seats against the capscrew. Drive the guide out by beating on the drift with a hammer. The guide will stretch in the process, getting thinner—and will slide out. If the guide is stubborn, heat the head to 350° and go back to work with the hammer.

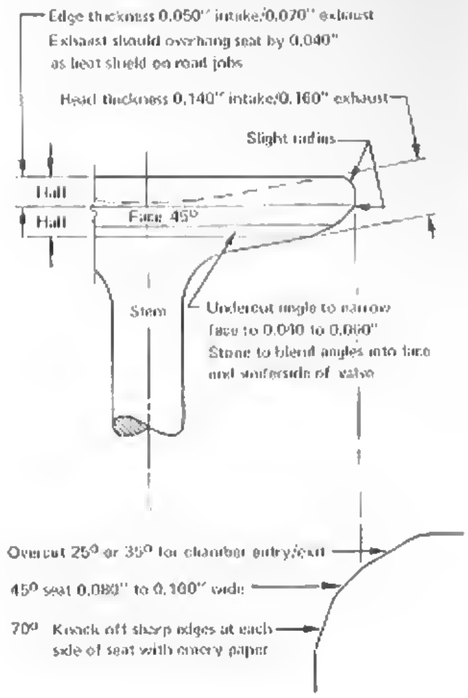
Coat the guides with some kind of lubricant before pressing or driving them in to help avoid galling. White lead or moly can be used.

Installing the guides is done with a stepped drift attached to an air-chisel "chatter-gun"—or pounded in with a hammer. Or, a press can be used to install the guides if the head is securely supported on a plate which angles the head correctly.

Best results will be obtained for installing guides—or valve seats—by heating the head to 450° F. Heat makes the head swell so that the guides (or seats) will go in with a minimum of effort. They'll be securely held when the parts equalize in temperature.

The step drill and drift cost about $15 total from Baum Tools. And, if you are doing much work on a VW, you'd better invest in an 8 mm guide reamer.

VALVE FACE & SEAT DETAILS



EVERY VW NEEDS A VALVE JOB—EVEN A NEW ONE

Any VW with 10,000 miles on it needs a valve job to sharpen up its performance. And, if your VW has gone 50,000 miles, there's an especially good reason for doing a valve job: this is the "magic number" for exhaust-valve failures. When the head comes off of an exhaust valve—a common problem with VW's—you'd better believe that the total cost will look more like a complete engine rebuild instead of just a simple valve job. Ray Litz suggests that 30,000 miles may be "plenty" for fuel-injected VW's.

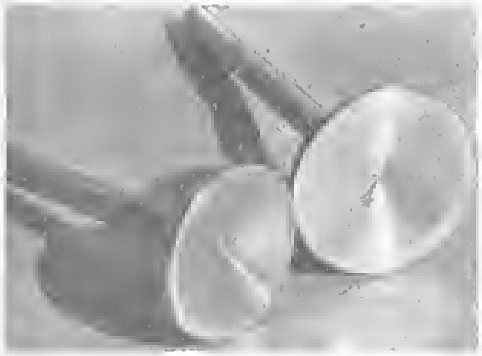
But, not all valve jobs are alike, and you'll not get much more performance out of a "run-of-the-mill" valve job from the local VW specialist or agency. Attention to detail, as described in this section, can mean as much as 3 to 5 HP gain by a "competition" valve job which takes full advantage of the valve sizes. The seats must be moved outward to coincide with the intake-valve edges, and seats widened to 0.080 to 0.100-inch on the exhausts and 0.100-inch on the intakes. Seats which are narrower reduce flow through the ports. The valves should also be undercut to reduce the actual width of the seat on the valve itself as described in the section on Air Flow.

The use of emery paper to radius the seat edges—both into the port and onto the chamber floor entry angle cut—is highly recommended as another way to eliminate eddy-causing and flow-robbing sharp edges in the flow path. This tip was provided by Jim Herlinger, who has built numerous successful Formula Vees.

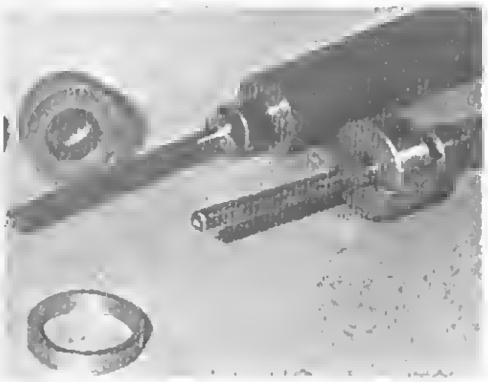
Even if you are starting out with brand-new heads and don't intend to do any of the porting and air-flowing magic which is described in this chapter, buy a precision competition valve job so that the engine will be that much closer to its advertised horsepower rating. Expect it to cost about $35 to $45, plus parts.

SPECIAL VALVES

Manley Performance Engineering manufactures four one-piece stainless-steel high-performance valves for the VW 1500 and 1600 cylinder heads. These have a tulip shape under the head to promote air flow through the port. Priced at about $7.00 each, these valves



40 mm intake and 35 mm exhaust of forged stainless steel are made by Manley. Same type valves available in stock sizes.



Piloted cutters and drivers for installing valve seats. Cutter shown should be used in a sturdy mill to ensure cutting a round hole. A cutter for drill-press use should have six or more flutes to get a round hole.

Driver for seat installation pilots in guide. Head should be hot to get best interference fit without broaching hole with seat.

are an excellent bargain for the VW performance enthusiast. S608 and Z609 drop right into the stock guides and seat on the stock seats.

Installation of Manley's S570 and Z569 or any other big valves is somewhat more complex. The stock seats must be removed, usually by arc-welding a bead around the inside of the seat to shrink the seat so that it almost falls out or can be tapped out easily with a long chisel. The head must be machined for larger seats (supplied by Manley and others) which are installed with an 0.007 to 0.013-inch interference fit. The head should be heated in an oven to 450°F. A seat driver which pilots in the guide is usually used to install these seats because this tends to insure that the seats go straight into the head without cocking sideways.

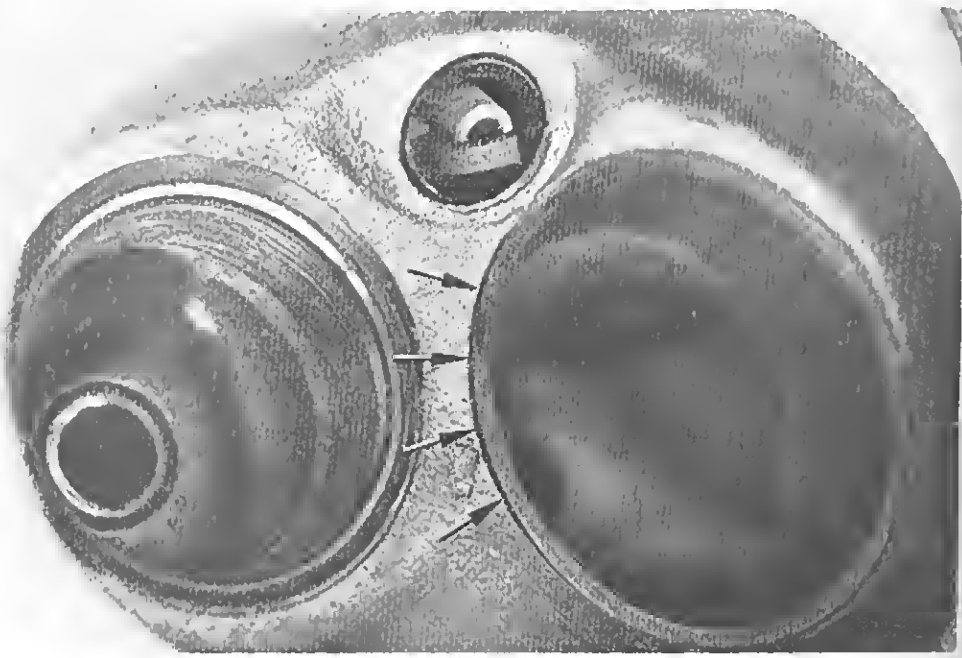
When porting the head so that the new seats blend into the ports, follow the general plan described in the air-flow section of this book, making sure to leave the buss in the exhaust port, thinning it as already described. Be sure to retain the radius which directs the flow into the port (below the seat towards the intake and ending just above the guide boss), even though you enlarge the radius to blend in with the underside of the new larger valve seat.

Manley	Valve Diameter	Stem Diamete
S608	35.5 mm intake	0.3125
A609	32 mm exhaust	0.3115
S570	40 mm intake	0.3115
A569	35 mm exhaust	0.3115

NO SHARP EDGES OR EXPOSED THREADS

Sharp edges are not wanted in VW combustion chambers because they cause detonation: destructive knocking caused by rapid and uncontrolled ignition of the fuel mixture at the wrong time during the engine's operating cycle . . . Therefore, you must eliminate sharp edges wherever they occur in the combustion chamber. Valve edges often require radiusing, and chamber edges at the sealing surface are other offenders. Plug threads which are exposed when the plug is fully torqued into place are prime troublemakers. If threads of the plug boss are exposed when the plug is installed, grind back the exposed threads so that the plug end comes flush with the chamber when torqued in place. Attention to these details is vital for your engine to live.

Oversize seat—or any seat—should not stand higher than the combustion chamber when it is installed. For best retention, seat should be a few thousandths below the floor of surrounding chamber.



COMPRESSION RATIO

In general, the average dual-purpose VW, or even cars used solely for transportation, should be equipped with a true compression ratio of 9:1 to 9.5:1 maximum. Premium gasoline is required with this amount of compression.

Racing engines may be able to tolerate compression ratios of up to 11.5:1, but anything much higher than this is not going to run very well on any kind of gasoline that you and I can buy . . . and the problem will soon worsen with the swing to non-leaded gas. The reason that a racing engine can tolerate a higher compression ratio is that camshafts with lots of overlap reduce low-speed pumping capabilities of the engine. Higher compression ratios offset some of the loss of low-speed torque which is caused by large amounts of cam overlap. Ray Litz says that some drag VW's are running compression ratios in excess of 13:1, but no one has proved that they have thereby gained any advantage over those racers using 11:1.

COMPUTING COMPRESSION RATIOS

These sketches, descriptions and formulas take the mystery out of computing compression ratios.

Measuring cylinder volume is not necessary—it's easier to compute it from the bore and stroke. **Cylinder volume = 0.785 x bore diameter^2 x stroke.** Deck-clearance volume can be measured by holding the cylinders onto the cases with hold-down washers and spacers under the stock head nuts. A depth micrometer, caliper or feeler gages can be used to measure the distance between the piston crown and the sealing surface of the cylinder at TDC. Be very careful that you do not break off the cylinder fins when holding the cylinders on in this fashion. It's very easy to do.

Deck Clearance Volume = 0.785 x Bore Diameter^2 x Deck Clearance. Combustion Chamber Volume is easily obtained, but by a slightly more complicated process which is described under Head CCing.

NOTE: Cubic inches are converted to cubic centimeters by the formula

Cubic Inches x 16.4 = Cubic Centimeters. If you have Cylinder Volume, that is V_1 in the formula, and if you measure the deck clearance so that you can get the Deck Clearance Volume, then you have V_2 for the formula. And, if you CC the head to find out the chamber volume with the plug and valves installed, you have V_3 for the formula. Just crank these figures into the following:

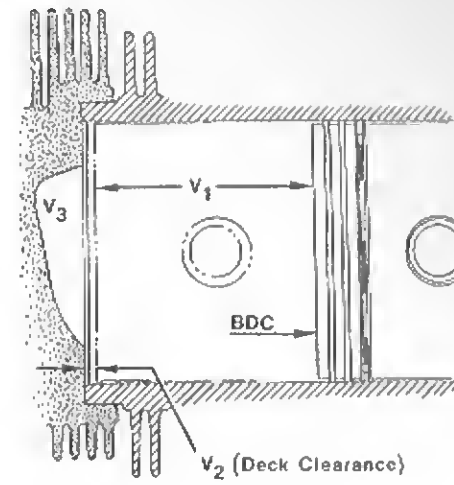
$$\frac{V_1 + V_2 + V_3}{V_2 + V_3} = \text{Compression Ratio}$$

Remember that cylinder displacement or volume V_1 affects compression ratio. Anything you do to increase V_1 (bigger bore and/or longer stroke)—or to reduce V_2 or V_3— automatically increases the compression ratio. If you plan to rework your cylinder heads now for use on an engine which will later be bored and stroked, use your ultimate displacement of the final engine configuration to determine the head volume that you'll need eventually so that you can do the head work just once.

HEAD CCing

There are a couple of reasons for CCing the heads. Most obvious is the need to know the compression ratio so that it can be adjusted if it is too high or too low for intended use of the engine, fuel octane, etc. The less-obvious, but just as important second reason is that the cylinders should all produce equal power, and that requires equal deck clearance at each combustion chamber—and equal combustion-chamber volumes.

You'll need a chemist's beaker or burette graduated in cubic centimeters. Ounce graduations are not small enough for the required accuracy . . . one ounce is 30 cc's. A circular piece of clear plastic at least 1/4-inch thick and approximately the same diameter as the cylinder spigot in the head makes the job easier. Put a 1/4-inch hole towards the edge by the plug. The edge of the plastic is coated with grease and the plastic is placed in the spigot and pressed into place around the edges to insure a good seal.



V_2 (Deck Clearance)
Piston at TDC

The fluid you'll use is mixed from a quart of solvent and a quart of automatic-transmission fluid. This red mixture simplifies the procedure because it is easier to see than colorless light oil or solvent.

If the head to be measured is new, be sure that it is spotlessly cleaned in both chambers. Old heads must be boiled out, scrubbed clean of all carbon deposits, and preferably glass-blasted or sand-blasted. You'll also have to rough in a valve job on older heads because the valves must seal liquid-tight. If bigger valves are being installed in either new or old heads, the seats must be installed and the valve job roughed in because different size valves will change the volume. Valves should be lightly coated with grease on their seating surfaces and dropped into place. Screw spark plugs (all of the same type) into the combustion chambers.

Lightly coat the outside flat edges of the combustion chamber (where the cylinder would normally seal against the head) with grease and press the plastic piece into position with the hole over the chamber. Level the cylinder head. Fill the burette with the red solution to the zero mark at the top. Use the petcock to drain out any liquid required to get the level exactly on the desired marking. This is critical!

With the burette over the hole in the plastic plate, open the petcock and slowly fill the chamber. As the fluid reaches the seal between the head and the plate, watch for leaks. If there's any

Hydraulic press can be used to install guides if head is securely located on an angled plate. Heated head simplifies assembly and ensures tight fit. Lubricate guides.

Straight edge can be used to check that all valve stems are of equal height in relation to gasket rail. Quicker and more accurate measurements can be obtained with a dial indicator. Valves can be held on seats with light springs.

seepage between the head and the plate, you'll have to start over, including pouring out the fluid, cleaning out the chamber and resealing the valves and plastic plate with grease. Don't attempt any shortcuts, 'cause there ain't any. If you don't have any problems with the seal between the plate and the head, fill the chamber until the liquid just touches the bottom of the hole in the plastic plate. Tap the plate to chase away bubbles because they will affect the measurement.

Record the amount of liquid in the chamber and repeat the measuring process in the next chamber.

Assume that you have recorded the measurements of the four chambers as follows: 43.5, 41.7, 42.5, and 42.0 cc's. This would be close enough for a factory-assembled engine—but not for a high-performance job that is to give its utmost. We are going to make all of the chambers measure the same within 1 cc. What you do to make all of the chambers the same depends on the racing class or association rules by which you may be competing. By all means, get a copy of them and study the regulations regarding the combustion chamber shape and volume, valve configuration and so forth until you know what they say and mean.

Even if the rules permit lightly shaving off a few thousandths from the head of each valve, it is preferable to sink the valves into the head. Similarly, if the rules allow slight modifications to the combustion chamber, then using your rotary files to increase the size of the chamber at each valve as described under the Air Flow section may be the course to follow. "Sinking the valves" means moving the valve-seating face further into the head to increase the chamber volume. Think about what you are doing because any valve which is sunk can't be raised again unless you install a new valve-seat insert. If only a small amount needs to be added to the chamber, sink only the exhaust valve and leave the intake at stock height. If quite a bit must be gained, sink each valve a slight amount.

Sinking goes like this. Use a 25° stone to reduce the width of the exhaust seat and to unshroud the circumference of the seat. Re-establish the valve seat with several light cuts with a 45° stone. Carefully clean the chamber, grease the valves and reinstall them. Re-CC the chamber. Repeat these steps until the chamber equals the largest one which you originally measured . . . in this case 42.5 to 43.5 cc's.

Because there's no simple way to determine how far to sink a valve to get the needed extra volume, *go slowly.* Take off only the tiniest amounts of metal at each attempt. Remember that all combustion chambers are to measure within 1 cc. Nearly that close is not good enough.

Now that you have all of the chambers measuring the same, the question is—do you have the compression ratio that you need for the performance you want—or to meet class regulations? Calculate what combustion chamber volume you need. With one head levelled, valves installed and plug screwed in, pour that many cc's into the chamber.

Use a depth mike to measure from the head-sealing surface to the solution. As you screw the depth mike downwards toward the solution, watch for the solution to "jump" to the tip of the mike. When that happens, measure how far down this was from the cylinder sealing surface. This is what you'll have to flycut from the cylinder head spigots to get the required compression ratio. Don't cut more than the maximum recommended flycut or you'll have leaking cylinders and perhaps even another junk head. Be sure that the cylinders will enter the head fully or you'll have leaks. See the details in the discussion on how to flycut heads in this chapter.

NOTE: 0.001" flycut gives about 0.157 cc. reduction in chamber volume.

If you are running in a class where cylinder heads may get measured if you win, combustion chamber volumes must be measured after the flycutting. You may want to stop flycutting 0.005" from the desired value to measure whether your chambers are going to be "right on" tolerance. Chambers which are made too small by excessive flycutting could mean starting over with a new head. Be careful—measure a lot!

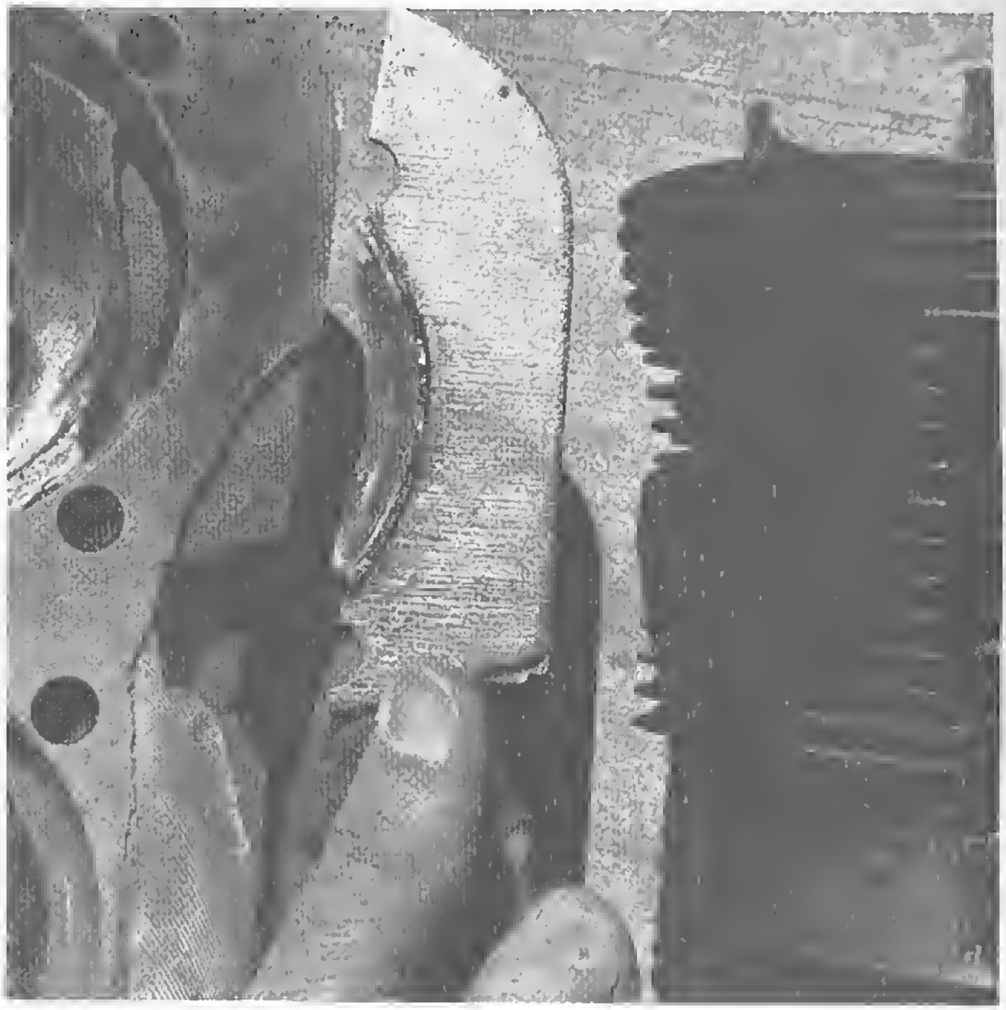
You've just eliminated one more of the variables which can detract from consistent high performance. Now there's another variable that you'll have to check. Install the valves with light springs,

retainers and keepers. Place two parallel bars (steel or aluminum) on the rocker-arm side of the head. Use a depth mike to measure the valve-stem heights. Mark each one down. Ground 1/2" x 1/2" x 6" tool bits work well as parallel bars.

Do this for both heads. Determine which one is shortest and bring all of the stems down to this level by refacing the valve-stem ends on a valve grinder. Be sure to mark the valves so that they can be reinstalled in the same cylinders, because the variation in seat depths requires that the valves always be reinstalled in the locations where you made the measurements. If you don't mark the valves before taking them out of the head, it could be quite a puzzle getting 8 valves sorted out as to where they go so that stem heights are equal. Getting the stem heights equalized is part of the job of getting the right valve train geometry, which is discussed in another section of this book. Check the heights again after the valves are back in the heads.

FLYCUTTING TO RAISE COMPRESSION OR TO REPAIR SEALING SURFACES

It is easy to raise the compression of your VW engine by flycutting the heads. In fact, it seems so easy that most engine builders completely overlook the fact that this is really one of the most complex modifications that you can make to a VW because it changes so many relationships. When you understand what the flycutting changes—in addition to the compression ratio—then you are on the road towards professionalism in your engine-modification efforts. Flycutting is also an easy way to reclaim heads which have had sealing failures where the cylinder meets the head. VW agencies often throw such heads in the junk pile because it is cheaper for them to use new parts than to reclaim the old ones.



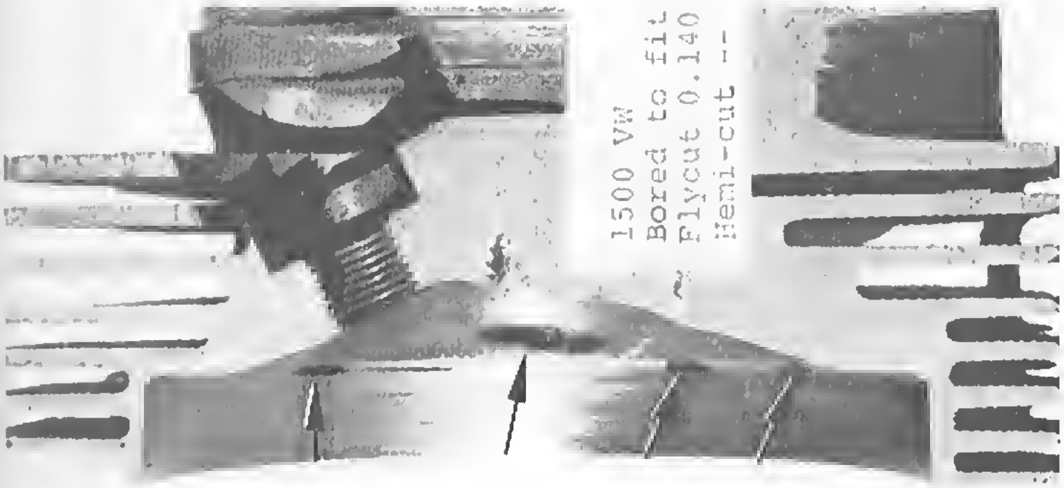
It's important to go easy on the flycutting when you use monster-bore cylinders. This head, flycut 0.140 inch and bored for 92 mm cylinders, lost a chamber, part of a fin, and blew out the top of a cylinder. When things get too thin—they break—inevitably!

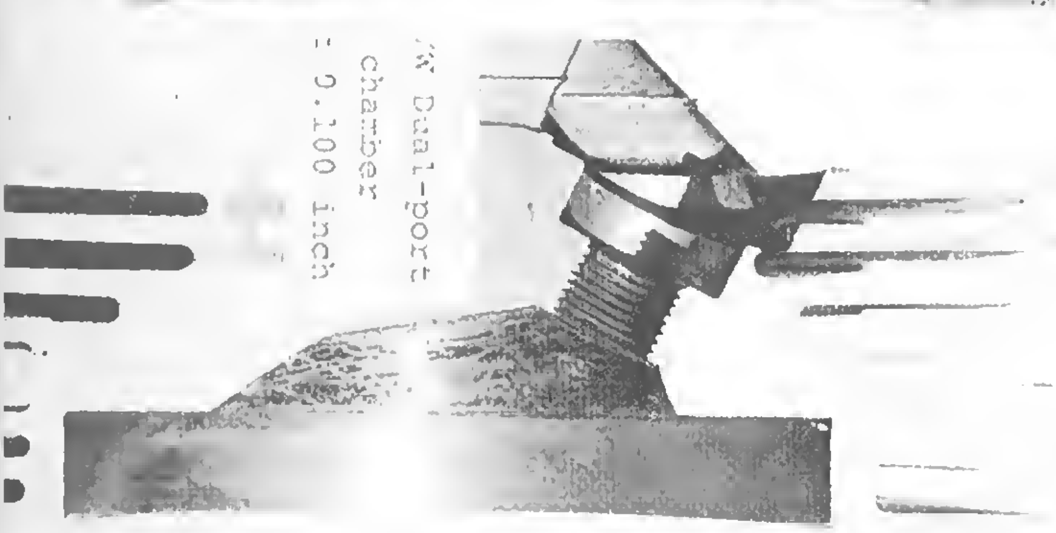
What changes occur when you flycut heads?

First, *the chamber volume is decreased.* As you deepen the flycut, the compression ratio is increased because the combustion chamber volume V_3 is reduced. That's easy enough to understand. But, if you are increasing the displacement V_1 of your engine by boring or stroking or both—those modifications also increase compression. So, before doing anything to the heads, decide what c.r. you want to use. Then, knowing the bore and stroke—and following the details under Computing Compression Ratios—figure out what the volume of the individual combustion chambers should be to provide the desired c.r. It is quite possible that you will discover that you already have a combination that will give you the desired compression without flycutting. If that's the case—so much the better. It is also possible that you will need to face off the case end of the cylinder base B for reduced deck clearance V_2. Reducing the deck clearance also reduces V_2—which raises the compression.

Second, *the heads are moved inward toward the crankshaft and camshaft.* This will always be true except in those instances where spacers are installed under the cylinders to accommodate longer strokes with pistons which do not have the correct compression height. The effects of moving the heads inward are usually overlooked by the casual shade-tree mechanic or novice. *The relationship of the valve-adjusting screw to the valve stem is changed,* moving the contact point toward the pushrod and causing two distinct problems. Performance is seriously reduced because this reduces the amount of available valve lift. And, friction goes way up because the valve stem is always operating in a cocked or binding condition in the guide. Valve-guide wear increases beyond belief. Running an engine in this condition can wear out the guides in less than 100 miles!

To remedy these problems requires either shimming the rocker-arm stands or reducing the pushrod length. Most articles which you'll read about VW modifications will zip right on past this point in a hurry by telling you to shim the rockers or cut the pushrods the exact amount that was flycut from the heads. Well, such simple





Top photo is sectioned 40 HP cylinder head flycut 0.100. Note adequate metal section to ensure a good seal around the cylinder. Counterbore (arrow) is for copper gaskets used to ensure that no exhaust gasses will leak into heater system if cylinder-to-head seal fails. Center photo is 1500 head bored for 92 mm cylinders and flycut 0.140 inch—with catastrophic results for the engine. Arrows indicate failure points.

If the head doesn't "fall through," most builders never understand why the cylinders consistently leak around the joint. Bottom: 1600 dual-port head (stock bore) flycut 0.100 In. has adequate metal section for cylinder sealing. Heads bored for 92's can usually be converted to 88's with a smaller step bore, although a spot of heliarc may be required.

answers won't work because they assume that everything else was measured and found to be correct in the first place—and that nothing else has been changed. Read the details on getting correct valve-train geometry. That information in the Camshaft and Valve-Train Section will help you to set up your engine so that the valve-adjusting screw contacts the valve stem end exactly right. You'll get maximum performance and minimum guide wear.

Another thing to check is the fit of the sheet metal. Some of the holes may have to be filed to fit and it is sometimes necessary to do a bit of sheet-metal reshaping to get all of the parts back together again. Any cutting or reshaping must be kept to a minimum and done so that there will be no loss of cooling air.

How deep to flycut?

As I gathered material for this book, I got all sorts of answers when asking about the maximum safe depth of flycutting for VW heads. I'll not even relate some of the 'way out dimensions which were quoted, nor embarrass the "experts" who insisted that their numbers were the hot setup. Fortunately I found a head which had failed at the sealing surface J and caused a section of the cylinder to fail at the same time. It had been flycut far less than many of the recommended "safe maximums" which I had been given. Gene Berg and I sectioned the head and then took the accompanying photos to show once and for all why deep flycuts cannot be recommended for VW heads, especially when bored out to accept 88 mm or larger cylinders.

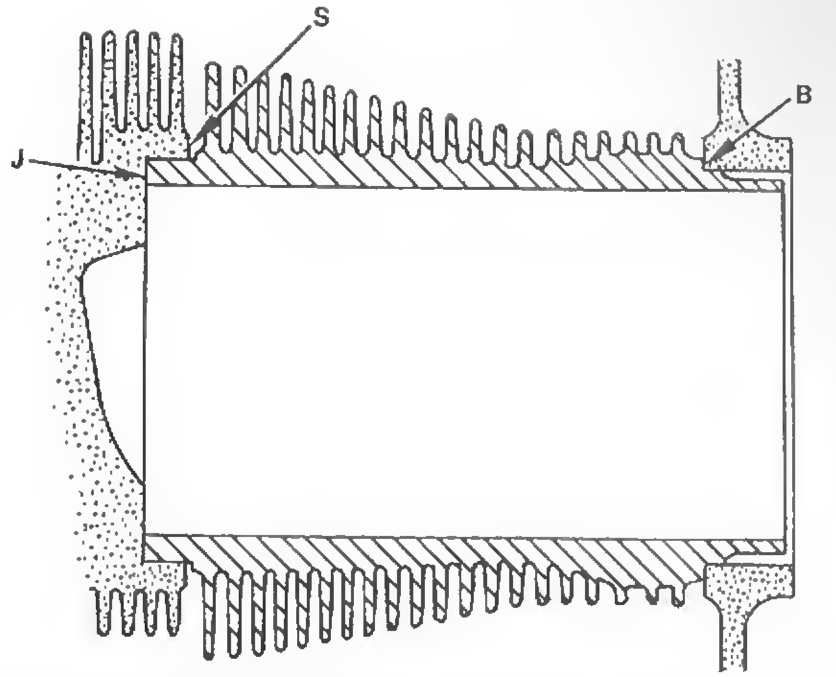
For road machines, do not flycut VW heads more than 0.100-inch for longevity. You can believe that anything deeper does not leave adequate metal for ensuring a good seal.

Racing engines with stock through 88 mm bores are usually built with 0.200-inch flycut, then compression is regulated by changing the deck height with pin height or cylinder-base spacers. But, if the 92 mm cylinders are used, the head may start to hole through at 0.100-inch, so stay at 0.060 or less for 92's.

How to flycut

If you have one of Gene Berg's head-flycutting and case-boring tools, you can flycut heads in a drill press. Complete instructions are supplied with the tool and I'll not try to include them here. Suffice it to say that flycutting becomes super-simple when you have one of the tools. The only outside machine work you'll need from an automotive or other machine shop is to have head fin surface **S** milled or ground off an amount equal to the depth of the flycut which will be made. Or use a counterbore of approximately 0.200" larger in diameter than the spigot diameter and same depth as the flycut. Keeps bottom fin from breaking up on deep cuts. The amount which is cut off should be measured from the knobs which are on most VW heads, or from the fin surface on heads without knobs. The flat rocker-gasket surface of the head must be held securely against the table of the grinder or mill.

When using a milling machine for this task, first take a true-up cut on the gasket surface of the rocker-arm side of the head. Dean Lyon says that this can be out by as much as 0.012" to 0.015" and it must be made true so that your next operations will come out right. Next, position the head on the mill table so that a centerline through the two cylinder spigots is parallel with the direction of mill table travel. Center one of the chambers under a cutter head adjusted to cut the spigot diameter which is required for the cylinders to be used with the head. The cutter should be ground so that the same cut makes the flat surface for sealing against the end of the cylinder. The cutter must have a 1/32" radius at its tip to avoid stress risers which could start cracks

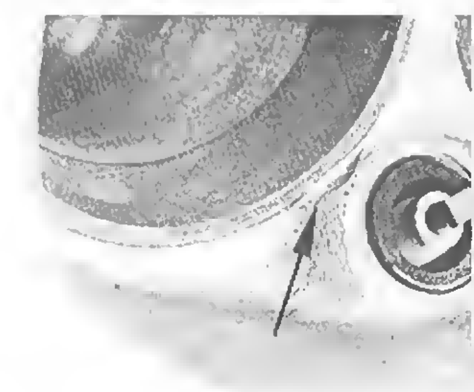


Here are surfaces and joints referred to in text on flycutting and blueprinting the VW engine. J is where cylinder seals against the head. S is fin surface of head closest to cylinder. B is where cylinder base seals against the crankcase.

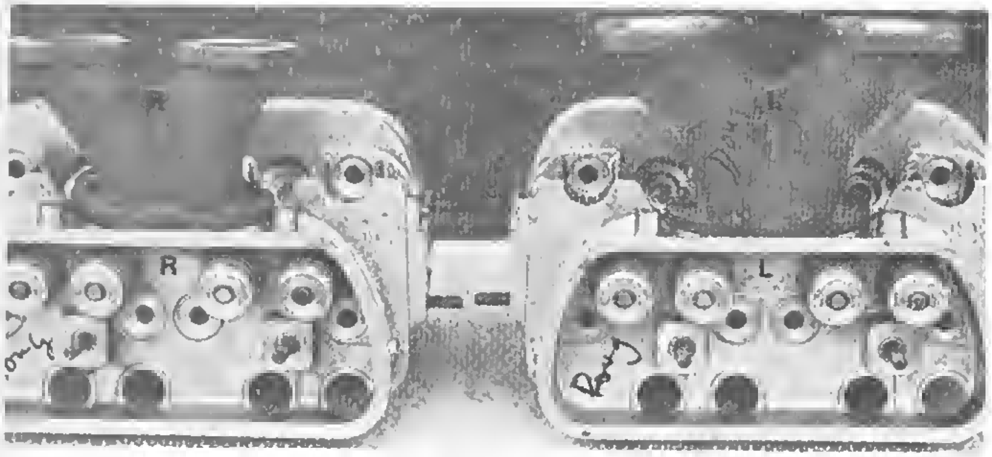
from the sealing surface edge. Ray Litz asked me to mention that not all cylinders are chamfered or radiused at the outside edge. It is essential to add such a radius or chamfer to clear the radius or the radius could hold the edge of the cylinder away from the sealing surface.

Before starting to flycut, measure the depth of the spigot from fin surface **S** to the sealing surface **J**. Or, if the head has six knobs on the fin surface (three at each spigot), measure from the knobs to the sealing surface. You'll find that this measurement may vary as much as 0.020 inch, even on the knobs for one spigot, but it should be approximately 0.510 to 0.540 inch. When you have finished the flycutting job your heads must have a spigot depth of not more than 0.525 inch so that the cylinder will insert into the head far enough for good contact at sealing surface **J**.

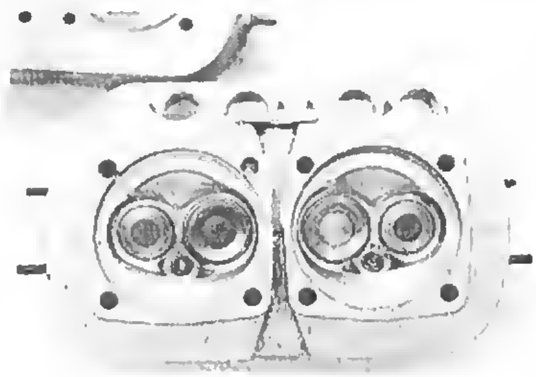
Jot down the mill setting at which the cutter just starts to touch the original sealing surface **J**. Cut a new sealing surface at the desired flycut depth to provide the chamber volume which you want. Record the depth of the cut and set the stop on the machine so that you can duplicate the cut in the next chamber. Lift the cutter out of the spigot and dial the mill table to the center of the next chamber. Flycut this chamber to the exact depth of the first one.



Proximity of 40 mm valve seat to plug boss shows why professional racers move the plug when really big valves—up to 44 mm—are installed.



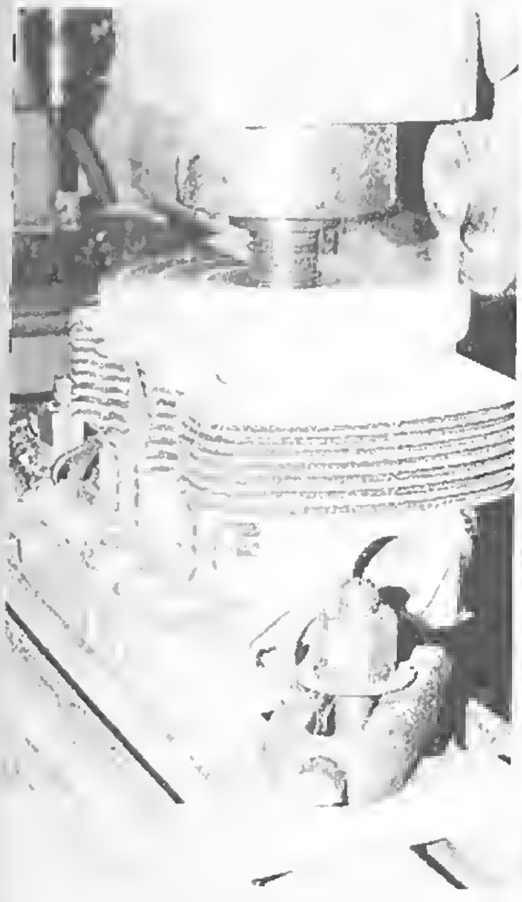
Heads and manifolds are identified **L** and **R** so matched ports in heads and manifolds will mate smoothly when reassembled. These heads from Doug Gordon's Underdog are fly-cut so deeply that the entire first fin had to be removed to avoid interference with the cylinders. Cutting through the fin at this location may help the head to conform to the cylinder sealing edges during rapid heating and cooling. Lower photo by Charles Evans.

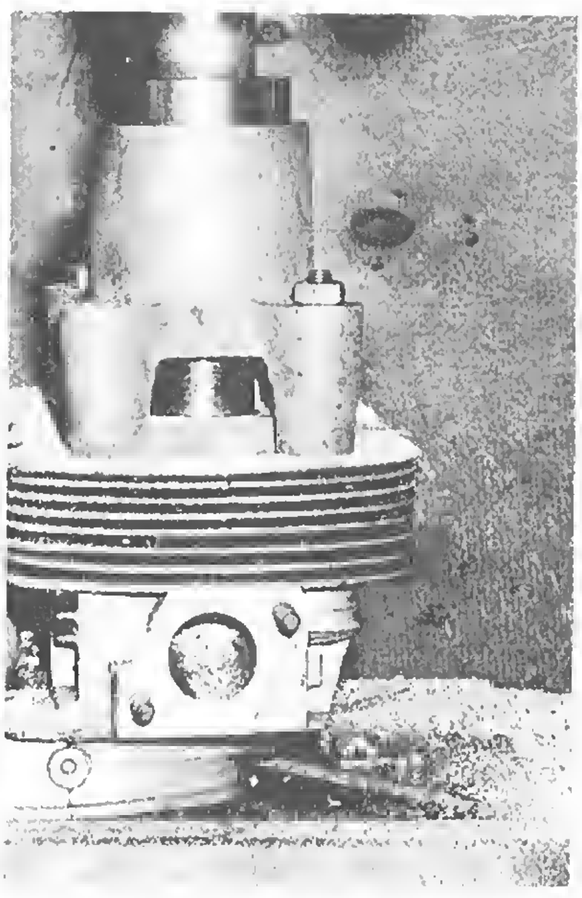


When you machine the second head figure the flycut depth from the original sealing surface **J** of this head, not from the depth setting used on the previous head. Head dimensions vary from the rocker-gasket surface to the sealing surface of the chambers, so don't set a stop when you've finished with the first head and expect that it will be perfect for the second head as well.

After finishing both heads, mill the fin/knob surface **S** on each head an amount equal to the flycut depth so that the heads will seal against the cylinders without interference with the top fins of the cylinders. If you have flycut 0.100 inch, mill surface **S** the same amount. As a double check, measure the end of the cylinder and compare it with the depth of the spigot just to make sure that the cylinders will enter the heads all the way. ACE prefers to counterbore a step with 0.200-inch larger diameter than the cylinder spigot diameter and the same depth as the flycut. This will usually provide clearance for the end of the cylinder so that it will fully insert into the head. The reason for the counterbore instead of a full surface mill of the entire fin is that this keeps the bottom fin strong so that it does not break off, even with fairly deep flycuts. Such counterbores require doing the flycutting job in a mill.

Be sure that the machinist understands that equal depth cuts are required in each spigot or you will have ruined heads and perhaps even ruined cylinders where the cylinders failed to seal.





Simple milling cut on rocker-gasket rail and then on fin surface readies head for flycutting or big-bore cylinder machining in a drill press with Gene Berg's under-$100 flycutter/casecutter tool. A boring plate is available which allows clean up flycuts (up to 0.100-inch) without cleaning off the fin surface. Same tool cuts step out of 1971-72 heads, reconditions sealing surface on any VW head which has failed at the cylinder-to-head joint. Tool is equipped with hardened shaft, oilite bushings and seals to prevent chip entry into bushings.

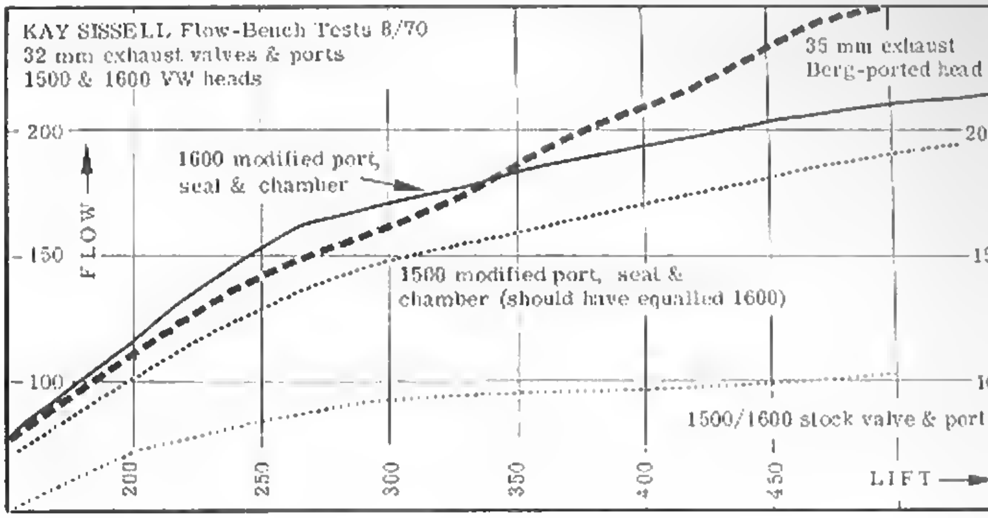
INTRODUCTION TO AIR FLOW

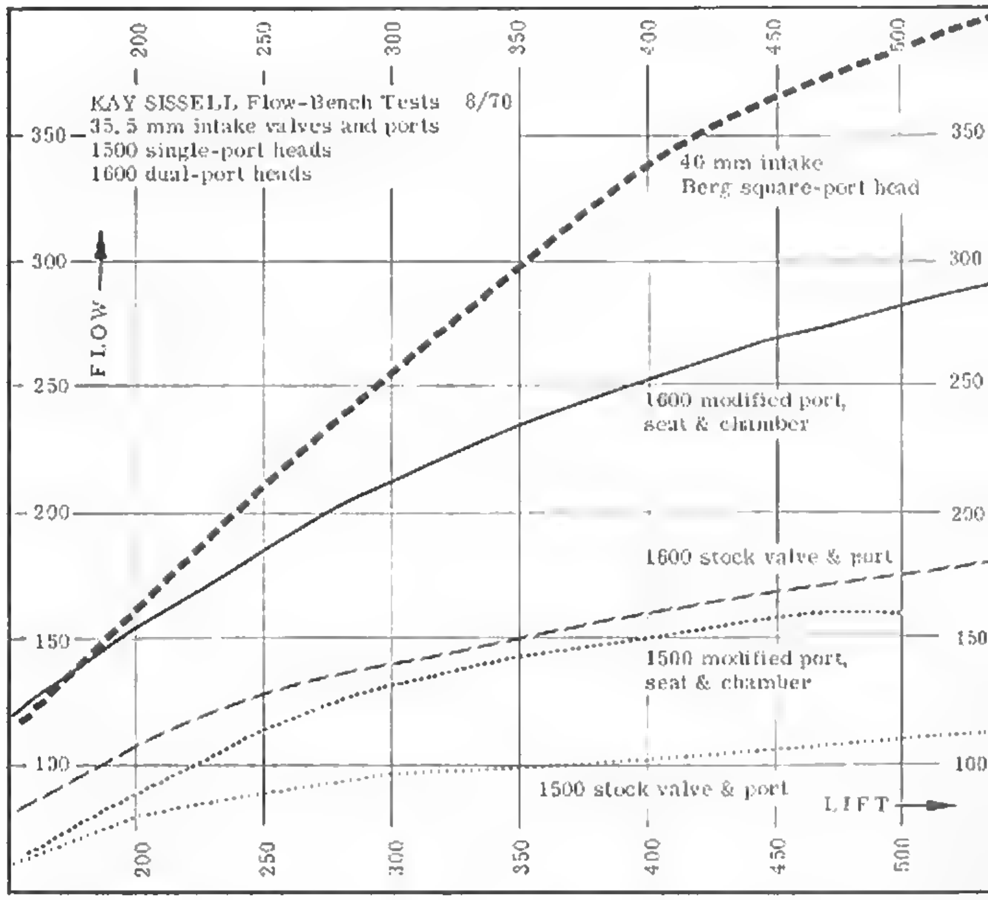
So long as VW hotrodders attempted to work with the stock crankshaft with all of its high-RPM flexing and torsional vibrations, there was no real reason to spend much effort in making the cylinder heads breathe better. Even mildly modified stock heads "made enough horsepower" to wreak havoc with the lower end. However, as roller bearing and fully counterweighted crankshafts became "standard" components in building hot VW's, lower-end reliability improved to the point where more breathing could be used to develop higher horsepower.

Porting is a term which has long been used to refer to modifications of the valve pockets behind the valves and the ports connecting the valve pockets to the intake and exhaust manifold flanges. For many years, engine modifiers "hogged out" the ports as large as they could get them, short of making holes in the port walls. If the pocket behind the valve could be opened up to the inner dimension of the valve-seating surface, no one hesitated to do just that. Little attention was paid to the combustion chamber into which the valves opened. In rare instances, tuners began to note that ported heads sometimes seemed to detract from the low-RPM performance of the engine. But, even those that noticed it didn't stop making big holes at least in heads for their customers—because that was what sold. It looked like the hot setup—whether it was, or not.

As tuners began to recognize that flow benches could be used to measure the efficiency of ports with various valve sizes and lifts—with different port shapes—a lot of the old "hog it out" approaches were discovered to be detrimental. The use of flow benches has also caused hotrodders to become more conscious of intake manifold design requirements—including the size of the carburetor which is feeding the system.

Because so many ported heads actually flow less air than the stock heads, I thought that it was highly important to provide the readers of this book with some guidelines as to what can be done to improve air flow in the VW cylinder heads without taking "giant steps backwards." *Porting* is now a "wrong" word because it does not embody all of the modifications which work together to affect air-flow characteristics through the intake and exhaust ports.





One factory which has done lots and lots of air-flow research is the Chevrolet Division of GM. Their small- and big-block engines have long proved their horsepower-making capabilities and as a result, Chevy-based race cars dominate every racing class in which they are eligible. Because one of the elements which assists in the superb air-flow characteristics of these engines is valve shape, we tested Chevy high-performance valves in our investigation of ways to make VW heads flow more air. Cutaway drawings of famous racing engines, especially those with small displacement, reveal valve shapes which "work" with the port and valve pocket to get more air into and out of the engines.

Combustion-chamber shaping is also extremely important because the valves "work" into and out of the combustion chamber. A chamber shape which shrouds the valves so that they can't work sharply reduces air-flow

capabilities. However, as you will note, what shrouds a valve in a Chevrolet may not be what shrouds a valve in a VW. Every engine is different. You can apply some of the things which are learned from one engine to another engine, but porting and combustion chamber design require careful investigation for each specific engine on which you may be working.

Valve size becomes important because larger valves will usually enhance the flow characteristics of the cylinder head, even with poor port entry angles, especially when the chamber and pocket shaping are designed to work with the larger valves.

If you are one of those die-hards that hasn't got the message yet—let's say that it is now "smarter" to leave the ports and valves like the factory made them unless you have access to a flow bench so that you can see what removing a certain bit of metal from a port, combustion chamber or valve does to the air flow. Or, read what this chapter has to say—and follow its instructions carefully. They are written as a result of tests which were conducted precisely for the purpose of helping you go fast without investing in the same kinds of time-consuming hard work at the flow bench.

You may wonder why I've gone into such detail when a pair of VW heads can be basically ported commercially for about $125. That is a lot of money to pay. By showing you what is necessary—and what really works—you may be able to port and seat your own heads and use the money for a set of big-bore cylinders, a cam kit, or a manifold and carburetor. Also, by revealing which changes improve air flow, a lot of the unnecessary and harmful work which has previously been considered necessary because "it looked right" can be eliminated . . . and the basic price for porting and seating could come down. However, don't jump to the conclusion that you can now do your own "basic" porting job and then expect a professional to finish the job to the ultimate for less money because of your efforts. Those fellows rightly expect to start with a set of new and untouched heads.

There are now professional head-modification experts who will modify the combustion chambers, along with the intake and exhaust ports—in conjunction with flow-bench tests. These same firms supply shaped valves to provide better air flow than you can get with the factory-supplied stuff.

Prices for this work on your pair of new VW heads typically runs from about $125 for the simplest porting job with stock-size valves . . . to over $300 for a square-port job with big intake and exhaust valves. Lest you think that the firms that do these jobs are getting rich at these prices, let me assure you that they are barely making wages. There are a lot of hours of work in a good set of heads, far more than you'd ever guess unless you have done them.

MAKING VW HEADS WORK

My original plan for this section was to include details for installing larger valves and show you a few photos of "trick" porting and combustion-chamber reshaping currently in vogue in Southern California. But, my friend Kay Sissell—renowned six-cylinder expert in South El Monte, Calif.—insisted that I use his flow bench to see what improvements could be made to the stock VW head with stock valve sizes. As his own heads are known performance improvers for 6's of all types and large-block Chevrolets, Kay was hinting that there was good reason to perform these tests. This flow bench and Sissel's assistance to Gene Berg and myself provided the most significant porting information that I have ever been able to gather for one of my books in over 20 years of automotive publishing.

Over 1,000 flow measurements and three long days later we had found which changes would help you to get more horsepower from stock-size valves. And, we had disproved a lot of theories about what will—and won't—work on a VW head. No, we did not get into the details of making large-diameter valves work in VW heads. But, when we finished we were getting as much flow through the stock 35mm intake valves as we had been getting through 40mm intakes previously—that should tell you something.

The flow bench showed beyond any doubt that the novice must confine his head-modifying activities to those explained in this section. Even experts should give careful consideration to what is said here. Avoid "exotic" modifications until you have access to a flow bench, a pile of junk heads—and lots of time. From what we discovered on Sissell's flow bench, I'd have to admit that this is one of the best ways to find horsepower in any engine. Experts have long said that the engine is an ill-conceived air pump—if you can get more air into and out of the engine more horsepower comes at the same time "for free." *Free horsepower is tough to get.*

The graphs show where the stock valves stopped flowing, even with added lift. Racer Brown had told me that flow-bench tests would quickly show how much lift the VW engine really required and he was 100% correct. Bear in mind that we only scratched the surface in this series of tests because I was not trying to write a whole book about VW head modifications. However, lest you think that this all comes quickly and easily, let me point out that we worked almost non-stop for three days on just three ports so that you could read about how to get more air flow through stock valves in your 1500 single-port or 1600 dual-port heads. The same approaches are applicable to your smaller-valved 1200 and 1300 VW heads. I can assure you that we did not achieve perfection or maximum air flow on any port/valve combination.

From the curves you can see that the 1600 dual-port head is the answer if you want real performance from the VW engine. Its box-stock intake flow is almost as good as you can get with extensive modifications to the single-port 1500 head—and a competition valve job makes the dual port flow more than you can ever hope to get through the single-port. The exhausts, of course, are essentially the same. The tiny-valved 1200 and 1300 heads would respond similarly to changes as detailed in this section, but you would have to install larger valves to "come even" with the 1500 single-port. When we started the tests I secretly hoped that we could modify the single-port heads to flow as much air as the dual ports. I did not believe that the dual ports could possibly be as much better as they are.

We made our tests in what seemed to be a logical sequence. First, each port was "flowed" to get base readings for further comparisons. Then, each modification was followed by a series of flow measurements . . . usually to 0.500-inch lift and sometimes to as much as 0.600-inch lift. I have summarized what you should plan to do to your heads. The photos show details as to what you should and should not do to your heads.

No exotic tools were used because most readers do not have them. In addition to valve-seating equipment, we used a 1/4-inch variable-speed hand drill with rotary files. The only file that might be difficult to obtain was an olive-shaped 1/2-inch diameter one with a 4-inch-long shank. Here's a tip for you. When you use rotary files in aluminum they clog up so fast that you will become frustrated and aggravated unless you know the simple trick which keeps them clean. I've always used a bar of hard soap, but Sissell prefers a mixture of beeswax and oil. Berg uses tallow sticks. Dean Lyon, a machinist friend of mine, sprays WD-40/Penetrating Oil onto the parts to be cut. In any event, when a file loads up, just spin the tool slowly in soap or whatever—or spray on a little more WD-40—and go back to work. The tool cleans itself with absolutely no work on your part.

You may wonder why there is no reference to polishing the ports when they are finished. The reason is that polished ports "look fast" but add no air flow. So, I suggest that you use that same amount of energy to polish the combustion chambers very carefully without changing their shape. Sanding sleeves and Cratex abrasive impregnated rubber polishing tools work fine for this chore but use them in your electric drill. If you own a high-speed air or electric grinder, be sure that you do not run any tool above its published RPM limits. If the tools are sold from an open bin, or with no instructions—find out what safe speeds are in the manufacturers' literature or you can injure yourself when a tool bends, breaks or disintegrates. Wear goggles or safety glasses every time you do any cutting or polishing. I can assure you that chips in the eye are painful, time-consuming and expensive—and painful.

1200 & 1300 Heads

For best performance, replace these heads with the dual-port 1600 or single-port 1500 heads. New heads cost less than you'd pay for installing the larger intake and exhaust valves—and they give you the advantage of new guides and clean heads to work on. If you keep the heads, install new guides, seat the valves and modify the seats and ports as described for the 1500 and 1600 heads.

1500 & 1600 Single-Port Heads

Intake Seats & Valves: Sink the intake-valve seat up to 0.100-inch into the head to "pocket" the valve. Make the 45° seat 0.090-inch wide to 0.100-inch wide, with a 70° cut on the inner diameter and a 35° cut on the outer diameter of the seat starting at the valve outer circumference. The combination of sinking the seat and the 35° angle provides a wide entry surface to the chamber floor and promotes flow. Some automotive machinists will argue that narrower seats work better and that sinking the valves wrecks the head, but you can be sure that they have never run any flow-bench tests on VW heads. Grind a 30° angle on the underside of the 45° sealing surface to cut the actual seat on the valve itself to a 0.040-inch width.

Intake Port: First, seat the valves as previously described. Without removing the guide, radius under the seat with a 3/8-inch-diameter olive-shaped rotary file. Radius only that area illustrated in the photo and only enough to round off the sharp edge into the shelf under the seat. Leave the "lip" just below the valve seat. With a 1/4-inch-radius file, cut the chamber to the actual diameter of the cylinder bore to unshroud the valve. This cut should only be as wide as the

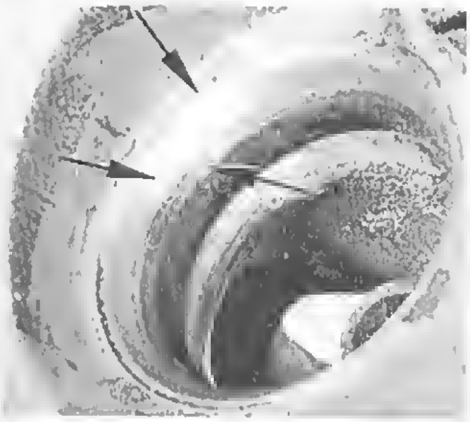
FLOW TEST

35.5 mm intake, 1500 single-port head

Lift/test	1	2	3	4	5	6	7	8	9	10	11
.150	60	62	64	70	73	70	80	80	80	84	80
.200	78	88	90	94	100	92	108	102	108	113	110
.250	89	99	102	110	111	108	124	118	121	131	130
.300	94	103	113	118	121	116	134	130	130	142	140
.350	101	104	118	121	126	120	142	133	141	153	151
.400	103	105	121	128	130	125	150	140	149	162	161
.450	108	109	124	130	132	130	152	145	152	168	170
.500	109	110	129	132	135	130	158	150	157	171	176
.550	110	111	129	133	135	130	160	----	160	173	182

1 - Stock valve and port.
2 - Competition valve job. 35°/45°/70°, approximately 0.100-inch-wide seat, valve sunk 0.100 inch. Back side of valve angled to reduce width of seat on valve.
3 - Radiused under valve seat into inlet tract with 3/8-inch rotary file for slightly more than 180° of seat opening. Radius started approx. 3/8" under top of seat.
4 - 1/4" radius rotary file around chamber at shrouded side of valve.
5 - Same tool used to unshroud valve to 88 mm bore diameter for width of valve only. Going any further to either side of the chamber reduced flow.
6 - About 1/16 cut taken off of non-plug side of chamber to unshroud valve further reduced flow as did similar cuts on opposite side.
7 - Straightened port inlet, removed bump from port, removed metal from bottom of port from the manifold side with a long-shanked rotary file.
8 - Radiused 45° seat into 70° angle. Lost flow, possibly due to removing venturi effect at this point.
9 - Same with competition guide installed.
10 - Port trimmed so that boss remained in place for guide.
11 - Guide boss cut out and port smoothed from both openings. Lip left below seat. Competition guide helped only above 0.400-in. lift.

NOTE: Where several things are grouped together, these represent the cumulative flow figures obtained to that point. However, each of the items listed was tested by itself.



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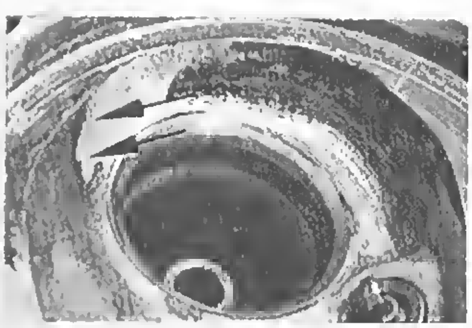

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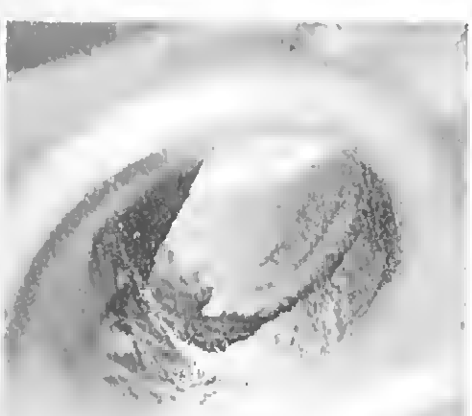

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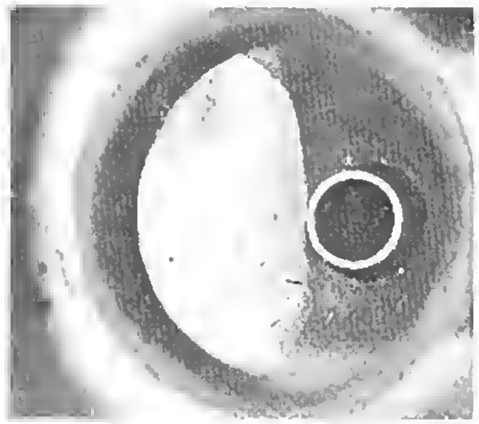

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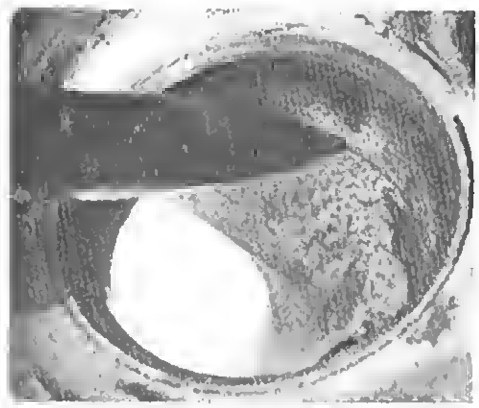

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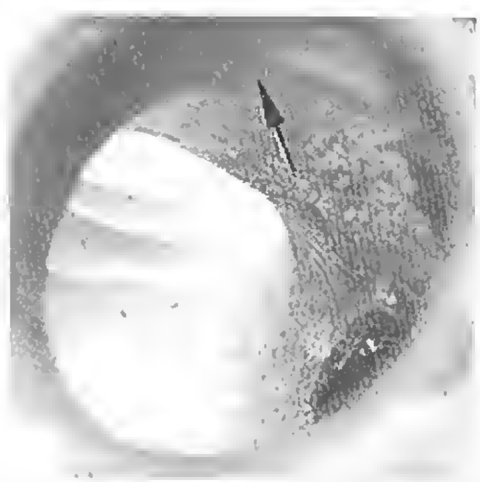

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11

Single-port intake modification is summarized in these photos which bear the same numbers as the test data on the previous page. 3 shows competition valve job with three distinct angles: 70° inner, 45° 0.100-inch-wide seat with 35° blending angle into chamber. Radius under valve seat into port runner was done with a 3/8-inch rotary file for slightly more than half of the circumference, leaving a lip below the valve seat. 4 shows where a 1/4-inch-radius rotary file unshrouded intake valve to scribed line at edge of 88 mm bore. 6 shows where slight amount of metal removed (arrows) on non-plug side of chamber reduced flow. Similar flow reduction occurred when metal was removed on plug side. Arrows indicate where you don't want to cut the chamber, at least with a stock-size valve. 7 shows the beginnings of straightening the port from the manifold side. 10 shows competition guide in port which has been cut away to keep the boss intact. This provided good flow to 0.400 inch. Unless you remove the guide, this is about the limit of intake-port modification. A competition guide has been installed in this photo. 11 - Removing guide boss gave best flow above 0.400-inch lift. Guide was removed for port work and reinstalled for test. Although guide boss has been taken out and the port given a gentle radius, note lip (arrow) below seat has been left intact to give a venturi effect below the valve. Note how port has been pointed toward manifold from valve side and vice versa. Valve has definitely been "sunk" into head—which helped flow considerably.

valve itself as shown in the photo. Straighten the port inlet from the manifold side, removing the bump from the side of the port towards the exhaust valve. With a long-shank rotary file, remove metal towards the bottom of the port from the manifold side. This is about as much as you can do to the port without removing the guide. To get maximum flow through the port, remove the guide and take out the guide boss so that the port is streamlined. A competition guide (shorter than stock, tapered end extending into port) can be installed if maximum performance is more important than guide life. Otherwise, install a new stock guide. Do not cut the guide off even with the port wall. Doing so drastically shortens seat and guide life and provides only minimal improvement in air flow.

Exhaust Seats & Valves: Use new valves because the exhausts have a tendency to break off where the head joins the stem, especially after 40,000 miles—and occasionally before that. The destruction which this creates is far more expensive than the price of a new set of exhaust valves. Don't gamble with older valves or you could be very sorry. Grind a 30° angle on the underside of the 45° seating surface to reduce the actual seat width on the valve itself to 0.040 inch. Use a 45° stone to sink the valve seat up to 0.100-inch into the head. The 45° seat should be 0.070 to 0.090-inch wide with its outer edge even with the outer circumference of the valve after you have used a 25° stone on top of the seat to provide an entry from the chamber floor. Sinking the valve widens the 25° entry angle and thereby promotes flow into the port. Use a 70° stone on the inside of the seat.

Exhaust Port: These modifications apply to all VW heads including both single-and dual-port types. First, seat the valves as previously described. Radius under the seat from the port to the underside of the 45° seat, removing 70° angle at header side of port only. Thin the guide boss toward the header only. Do not take out the guide boss or do anything which would change the radius cut in the port wall under the seat (towards intake valve). Carefully radius the 70° angle where it joins the port. Use a small grinder with an

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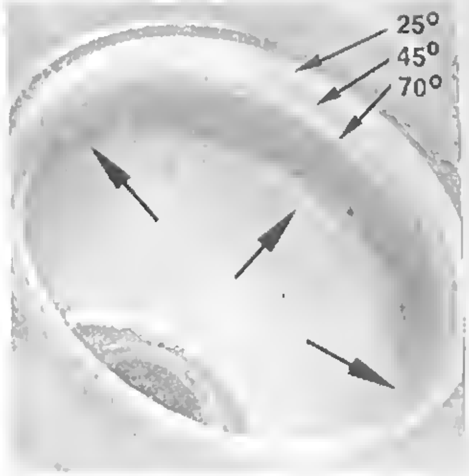

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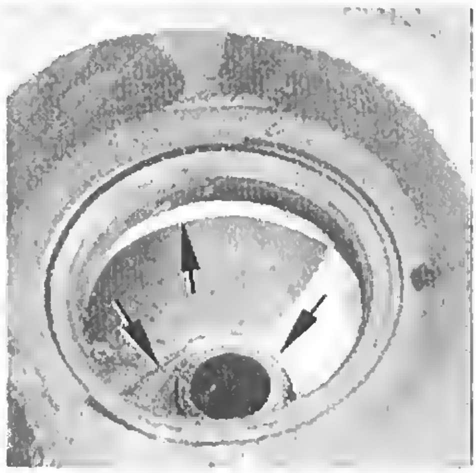

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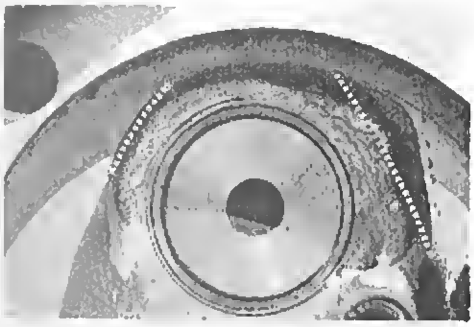
5

Exhaust port modifications for stock-size valves is similar for both single and dual-port heads. Photo numbers relate to flow-test data table for single-port exhaust.
2 - Avoid the urge to take out the radius (outline arrow) between the seat and the guide. Above all—leave that guide boss in place. 3 - Competition valve job here has three angles and widened seat: 70° on inside of 0.090-inch-wide 45° seat, topped by 25° stone cut to give shallow entry angle from chamber. Sinking valve widens entry-angle cut to promote flow. Area under seat radiused into port, starting immediately under the valve seat on the exhaust-flange side. Boss has been thinned without taking guide out of head. 4 - Shows thinned boss and seat insert.
5 - Shows clearance provided around end of valve when chamber is unshrouded at end of valve between arrows. Don't go farther than shown with the unshrouding efforts or you'll reduce flow. 7 - Shows unshrouding extended to bore diameter line scribed on blued sealing surface. Guide boss thinned on both sides. 8 - Shows finished exhaust seat/port/chamber with arrow pointing to clay which we had to use to regain flow after going too far with our unshrouding efforts.

8

abrasive stone to blend the angles. You'll need a good night's sleep and a steady hand here.

With a 1/4-inch-radius file, unshroud the end of the chamber to the bore diameter. Follow the details shown in the photo. Do not make any other modifications to the combustion chamber except for this unshrouding. A competition guide will not aid the air flow. Leave the stock guide in place or install a new stock guide.



1600 dual-port exhaust flow test 3 showed that extensive straightening of the chamber on the plug side lost flow below 0.300-in. lift. Slight flow improvement at higher lifts was not worth the effort—or the drastic compression loss. Stopping at the white dotted line is probably the answer for the stock-size valve. Additional chamber rework may be profitable with oversize valves, but should be confirmed with flow-bench tests.

1600 Dual-Port Heads

Intake Port: The following modifications can be accomplished without removing the guide from the port. First, seat the valves as described under the 1500 & 1600 Single-Port Heads. Radius under the seat to remove the shelf sharp edge. Radius the inside corner. Leave the "lip" below the seat intact. From the manifold side match the manifold and head flanges so that the head flange does not project into the manifold runners.

After looking closely at the photos, radius the port at the side closest to the rocker-cover flange, blending the opening into the port runner with a gentle radius. "Point" the port towards the valve with a long-shank rotary file from the manifold side. Do not remove the bump at the top side of the port closest to the rocker chamber. The port is *very thin* at this point. The new head used for these tests and photos had two pinholes. One into the rocker chamber appeared when we removed the bump—which did not improve the air flow. The other was into the intake-guide boss. If you open the port at the area closest to the rocker chamber there is an excellent chance of creating a hole which will have to be heliarc welded. Holes usually appear at the valve-spring seat. Welding the hole then requires remachining the seat and may also require making special part-circle shim washers to establish the correct installed height for that spring.

Use a 1/4-inch-radius file for the width of the valve at the end of the chamber, taking the end of the chamber out to the bore diameter as shown in the photo. The non-plug side of the chamber can be "laid back" slightly as shown *on dual-port heads only.*

Any other chamber modifications will cause the port to flow less air. The next step requires removing the guide so that the port side of the guide boss can be removed. This streamlines the port so that it flows more air. You can then install a stock guide which will give almost maximum airflow and excellent guide-wear characteristics—or a shorter, tapered competition guide which will provide maximum air flow with less guide life. Do not cut off the guide where it enters the port. Very little air flow improvement would be gained and seat life would be drastically shortened.

Exhaust Ports/Seats/Valves: Refer to preceding material on 1500 single-port heads as the dual-port heads get the same treatment. Exhausts are alike in the two head styles.

FLOW TEST

32 mm exhaust, 1500 single-port head

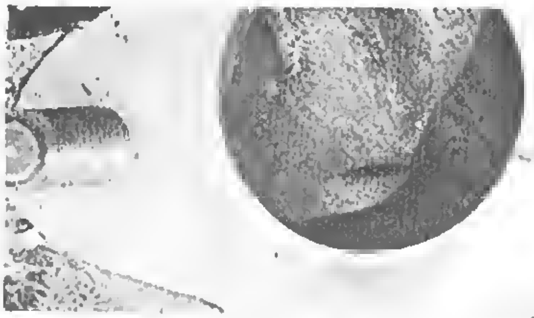
Lift/test	1	2	3	4	5	6	7	8
.150	50	60	60	62	60	58	68	75
.200	75	82	91	96	97	92	101	108
.250	88	92	115	118	126	118	131	138
.300	93	96	128	132	148	138	148	151
.350	97	100	138	144	163	149	161	161
.400	100	101	147	156	172	160	170	172
.450	101	102	156	166	181	168	180	182
.500	103	103	162	173	188	176	188	191
.550							193	198
.600								201

1 - Stock port and valve
2 - Competition valve job: $25^{\circ}/45^{\circ}/70^{\circ}$ with 0.090-in. seat.
3 - Radius under seat and each side of guide boss thinned, rounded off boss edge toward header-flange side
4 - Radius into port runner started 0.200-in. from top of 45° seat, actually cutting slightly into underside of seat.
5 - 1/4-in.-radius rotary file used to unshroud end of valve, 70° cut radiused into 45° seat carefully, slight cut back of chamber on non-plug side.
6 - Removed radius cut between seat and top of valve-guide boss. Note flow loss through entire lift range.
7 - Restored radius removed in 6 and unshrouded chamber to 88 mm bore diameter.
8 - Sunk seat about 0.100-inch, restored chamber on plug side, where removing metal had lost flow in one of the tests not shown here.

NOTE: Where several things are grouped together, these represent the cumulative flow figures obtained to that point. However each of the items listed was tested by itself.

1600 dual-port heads challenge the man wanting best flow through the stock intake valve. The challenge is leaving the combustion-chamber shape alone—with minor exceptions—and resisting the temptation to eliminate the tiny bump that protrudes into the port next to the manifold flange. 1 - That bump is the outer edge of a valve-spring seat and if you insist on smoothing it away, you'll be buying a heliarc repair job. Arrow points to hole we made by taking out bump. 1A - Shows where work started on straightening port runner to flow towards valve with stock guide in place. 1B - Shows where radius started under seat insert. 7 - Shows stock guide boss removed (required taking out guide). 9 - Shows valve sunk approximately 0.100 inch, giving broad entry angle to chamber floor. This helps air flow. 9A - Shows valve pocket straightened and radiused into port runner to straighten mixture path. 1/4-inch rotary file used to unshroud one side of valve. 11 - Same tool unshrouded valve to 88 mm bore diameter. 11A - Shows where an area was laid back on non-plug side for a slight flow improvement. Same type of cutting on plug side was detrimental. 11B - Shows how clay can be used to correct mistakes on a test head that you are learning on.

Here chamber is almost back to its original shape except for a small amount of unshrouding to the 88 mm bore scribe line. Unshrouding was carried into shrouding wall of cylinder with a slight undercut or cupping (arrow).



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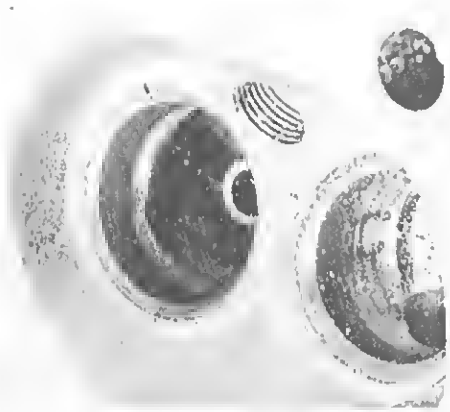
1A



1B

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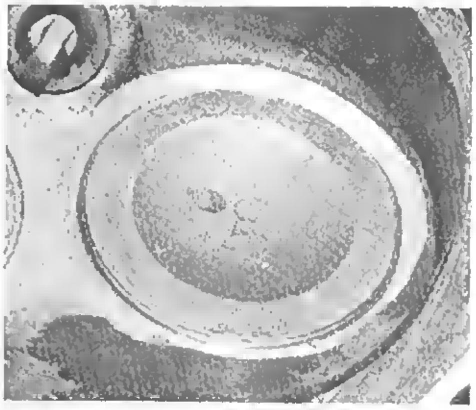

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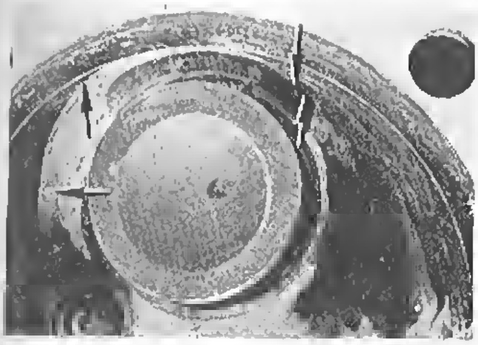
9A



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11A

11B

FLOW TEST

35.5 mm intake, 1600 dual-port head

Lift/test	1	2	3	4	5	6	7	8	9	10	11	12	13
.150	60	70	82	90	90	90	92	92	101	105	120	91	113
.200	90	100	119	126	132	131	130	132	143	143	160	133	160
.250	116	120	149	158	162	168	162	165	172	176	189	171	212
.300	130	140	169	186	190	192	190	193	200	210	212	208	254
.350	142	158	192	208	212	211	210	212	219	230	232	231	300
.400	151	175	208	218	222	220	228	230	238	251	252	258	336
.450	156	188	221	228	230	230	240	242	259	268	271	278	362
.500	160	199	233	241	245	238	250	255	270	282	282	288	382
.550			246	250	253	241	258	261	282	292	294	298	396
.600			252	255	258	245	260	265	291	300	302		400

1 - Stock port and valve.
2 - Point flow into valve pocket from manifold flange, radius under seat into port runner, take hump out by manifold (not recommended).
3 - Competition guide with seat width of 0.035-in., $20^{\circ}/45^{\circ}/70^{\circ}$ (note, the 20° should have been 35° for better flow into chamber floor).
4 - Same as 3 except 0.070-in.-wide seat
5 - Same as 3 except 0.100-in.-wide seat
6 - Stock guide with 0.100-in.-wide seat
7 - Boss removed from one side of guide (no help to 0.350-in. lift).
8 - Matched manifold at flange, stock guide, flange opening radiused into runner for straighter flow to valve.
9 - Straightened and smoothed valve pocket, leaving lip under seat, valve sunk 0.100 inch.
10 - Roll back non-plug side slightly (too much reduced flow)
11 - 1/4-in.-radius rotary file used to unshroud valve to 88 mm bore diameter, slight laying back of plug side of chamber.
12 - For comparison—drastically reshaped chamber with 40 mm intake valve. Note that it is only marginally better than the stock-size valve using a flow-bench-developed porting technique—and not as good as the stock valve up to 0.350-in. lift.
13 - For comparison—40 mm intake valve in square-port competition head by Gene Berg.

Note: Where several things are grouped together, these represent the cumulative flow figures obtained to that point. However, each of the items listed was tested by itself.

FLOW TEST

32 mm exhaust, 1600 dual-port

Lift/test	1	2	3	4	5	6	7	8	9	10	11	12
.150	52	60	52	73	62	92	82	90	81	62	64	75
.200	78	96	86	111	100	125	125	130	114	95	99	114
.250	88	114	108	140	132	152	152	159	146	128	132	143
.300	92	122	123	158	155	172	170	178	172	155	158	163
.350	99	135	137	168	171	184	182	186	184	165	170	191
.400	101	141	144	175	181	192	190	195	198	175	181	211
.450	103	144	151	181	190	200	196	201	209	181	190	236
.500		149	158	186	200	208	200	208	213	188	194	250
.550				191	208	211	204	211	222	191	198	
.600									226	196	201	

1 - Stock port and valve
2 - Port runner radiused to underside of seat, guide boss thinned, 1/4" radius rotary file unshrouded chamber to 88 mm bore diameter.
3 - Chamber opened toward plug side and straightened toward plug. Lost flow below 0.300-in. lift, reduced compression.
4 - 30° undercut to reduce 45° seating surface on valve.
5 - Seat moved to edge of valve and narrowed to 0.030 in.
6 - Seat increased to 0.080 inch width.
7 - Seat 0.070 with 20° entry to chamber floor.
8 - Seat 0.090 with 20° to chamber floor.
9 - Most of 70° under seat taken out with careful radius from remaining 70° in to 45° seat.
10 - Cut guide boss out of port.
11 - Same with competition guide
12 - For comparison—35 mm exhaust valve in Berg square-ported competition head.

NOTE: Where several things are grouped together, these represent the cumulative flow figures obtained to that point. However, each of the items listed was tested by itself.

SAVING TIME IN ASSEMBLY

If you are using a new crankshaft and rods, pistons, lightened flywheel and clutch, these items can be sent out for balancing *after you've made a trial assembly of the engine.* The rods can be assembled to the pistons and checked for alignment and end-for-end length—then marked so that all will be reassembled in the same groupings of rod, pin and piston. Mark the clutch and flywheel with paint daubs and bolt the two together without the disc. Cylinder-head reworking is another time eater and you may want to rework a set of new or used heads to reduce delays from this area. Buy or borrow another engine to use in the car while you are reworking your own. Then, if you have problems with your high-performance engine, you always have an everyday engine for getting you back and forth to work and to the pool hall.

It's a mistake to order a balanced assembly from a speed parts house if you are blueprinting your engine. It is o.k. to have the crank balanced, and the chopped flywheel (or stock) and the crank pulley. But, if you should find that the rods have to be rebushed or the pistons modified in any way for clearance or to get the deck clearance correct—then these parts would have to be rebalanced. You'll be money ahead in most instances by making the trial assembly first, then getting the parts balanced.

Zenith 32 NDIX was best single dual-throat carb for many years — until Holley introduced the Bug Spray. The by-pass oil filter shown here is not an acceptable accessory for a high-performance VW engine. Use a full-flow filter and protect your engine.

Pistons & cylinders
bigger is better — *usually*

VW Pistons are of the conventional flat-head, aluminum-alloy type with cast in steel struts to control expansion. Each slotted-oil groove piston is lightly tin-plated to reduce break-in scuffing. Clearance between the piston skirt and cylinder is 0.0016 and 0.0023 inch, measured at room temperature at the bottom of the skirt, perpendicular to the pin. At least four piston designs, all permanent-molded, have been used as detailed in the accompanying stock piston table. Note that the 1300 and later pistons have a larger-diameter pin. Pins are a light thumb-push fit in the piston at room temperature and can be said to be "full-floating" in the rod and piston. Pins are retained in the piston with circlips at each end. Incidentally, pistons used in the 1500S models—rare birds in the U.S.—had a slight dome on top of the piston.

Because VW had to have a bigger engine for their transporters as an option back in 1962, the Wolfsburg elves stuffed in the longest stroke crankshaft that would conveniently fit into the crankcase without drastic modifications. Instead of merely moving the pin boss higher in the piston, as is common U.S. practice, they lengthened the cylinders to accommodate the longer stroke. The result was a 1493 cc engine (91.1 cubic inches). The factory had no choice in 1965, when readying the first 1966 1594 cc (96.6 cu. in.) engine for more powerful fastbacks and squarebacks . . . they had to use a bigger bore with the same stroke.

With the 411 engine we see the cycle beginning all over again—with a 90 mm bore and a 69 mm stroke which is "stretchable" when the marketplace demands it. This indicates that Wolfsburg is thinking along Detroit lines—planning ahead for increased engine size with longer strokes.

Meanwhile, VW has attempted to discourage you from using larger bores by keeping the cylinder and head openings to the absolute minimum. This also strengthens the crankcase, in case you hadn't been thinking about that aspect. Most folks just buy the stock VW piston/pin/ring and cylinder assemblies for about $23 each and install only those parts which are required. But hotrodders learned long ago that cubic inches are the only absolutely trouble-free hop-up trick. They know that bigger bores are the logical way to go. As Tom Medley (publisher of Rod & Custom Magazine) said way back in 1947, "*When in doubt, bore it out!*" Unfortunately, you can't bore out VW cylinders. You have to buy bigger ones if you want an oversize bore.

When you start shopping for new pistons and cylinders, keep the stock prices in mind (and they sometimes go up, too) for comparison as you may find that replacement pistons in large bores cost less than genuine VW pieces—perhaps enough less to offset the costs for machining your heads and case to accommodate the larger bore, as discussed later in the chapter.

VW's own fine pistons are used to advantage when displacement is limited to stock size by class regulations, as in stock drag classes or Formula Vee. Even then, if you plan to use the engine for high speeds, a thousandth or so more clearance is needed on the skirts. Remove the heads and cylinders and add clearance by honing the cylinders. You do not have to remove the pistons from the rods or rods from the crankshaft—but like the old Indian scout—look for signs. Check the wear pattern on each piston to make sure that it is parallel with the piston-skirt centerline. If not, this is your "sign" that the piston is cocked and not travelling straight in the cylinder. Any piston showing uneven wear must be removed for alignment *with its connecting rod.* Twisted or cocked piston/rod assemblies steal horsepower through unnecessary friction and create unwanted heat and wear. You'll also want to look at the cylinder bores for similar signs.

If you are on the path of peak performance, don't leave anything to chance. Disassemble the engine so that you can have the piston/rod assemblies checked for alignment at an automotive machine shop. A complete tear down of the engine makes sense because it allows checking everything for wear, alignment, rebalancing, adding dowels to the crankshaft, installing a full-flow oil filter and so forth. Follow shop-manual instructions to clean the ring grooves and then check them for wear (side clearance on the rings). Check both ring-gap and ring-groove clearances before reassembly.

Replacement pistons and racing pistons — Some stock and replacement pistons can be used for racing, but not all racing pistons are suitable replacements for the stock items. Suitability of the various types depends on the intended use for the engine. Many replacements and racing pistons are available for the VW, including sand-cast, permanent-molded, die-cast and forged types. Of these, the forged Mahle or TRW pistons are the ultimate for several reasons. Forged pistons are made by forcing aluminum slugs into a piston form under extremely high pressures to create a very dense grain structure in the finished part. Forged pistons are claimed to have up to 70% more strength and better heat-dissipation characteristics than conventional sand-cast pistons. Their strength at temperatures over 600°F is far superior to any other type of piston.

STOCK PISTON COMPARISON TABLE

Series	Bore mm	Typical Deck Clearance	Pin Dia. mm	Compression Ring (mm)	Oil-Control Ring (mm)
1200	77	0.040/0.045	20	2.5	5
1300	77	0.040/0.045	22	2	5
1500	83	0.060	22	2.5 thru 1966 2 after 1967	5
1600	85.5	0.070	22	2	5

TRW, which makes more forged pistons than any other company in the world, has this to say about forged piston qualities and capabilities. "Forging starts with a billet of alloyed aluminum which is preheated to a working temperature and then formed. A multi-stage forming process allows control of the internal grain flow in the head, skirt, pin boss and ring land areas. The resultant piston blank has exceptionally high density with virtually no porosity. Sustained full-throttle, full-load operation substantially reduces the hardness and strength of the cast piston. The density and section shapes which are possible in the forged piston greatly reduce the temperatures in these critical areas, giving the forged piston a considerably higher operating strength range which makes it more resistant to head or ring-land distortion.

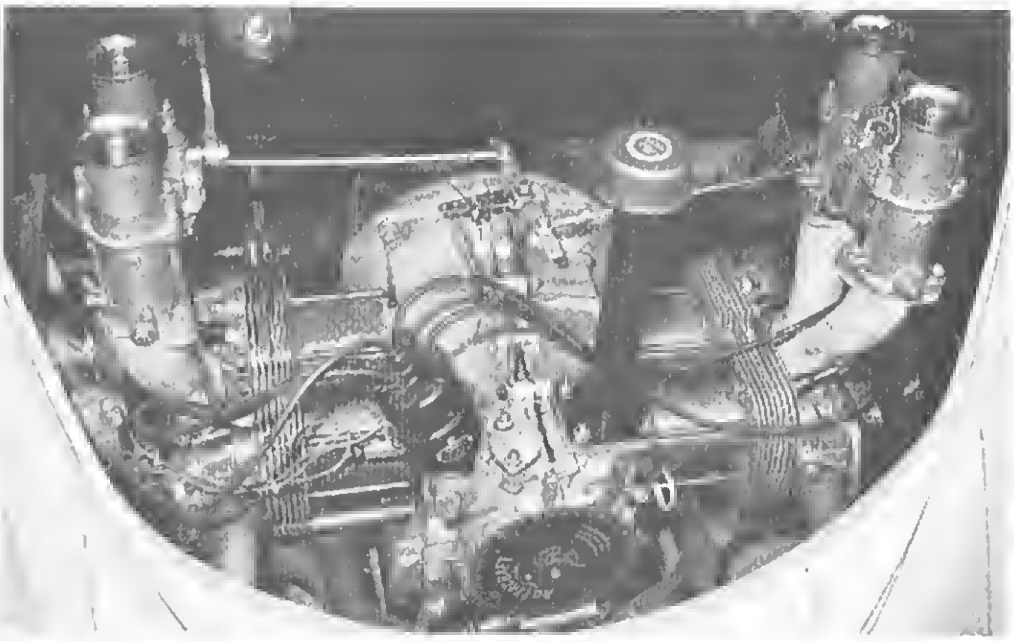
Several makes of pistons are available for the Volkswagen, and most of these come complete with pins, rings and cylinders—except the special pistons which are available from custom manufacturers.

Although forged pistons have a number of advantages over die cast and permanent-molded pistons, the initial investment required for the forging dies, and the use of more expensive production machinery, has kept most manufacturers from ever considering this method of manufacturing pistons for the VW. However, EMPI has offered Mahle forged pistons for VW's since 1966.

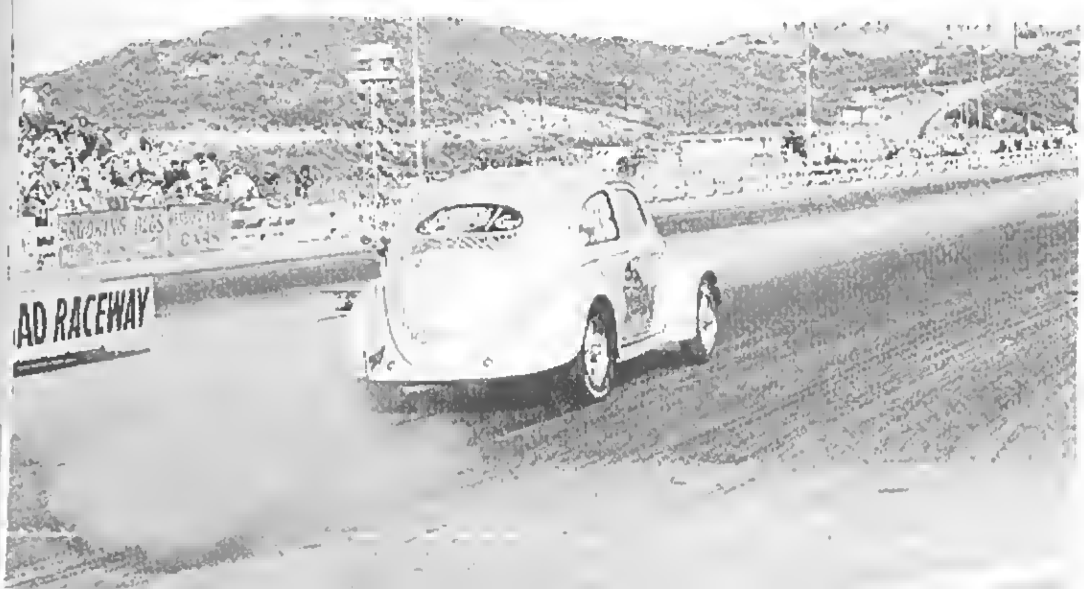
Almost any of the pistons will work o.k. for road or street use in a normally aspirated VW running on gasoline (non-supercharged), provided that the mixture strength and ignition advance are closely watched to avoid getting the pistons too hot.

Glass beading, knurling, grooving — Numerous engines have been assembled with knurled skirts deformed to reduce clearance. It is not recommended for new pistons and is a poor way to rework worn ones. Some builders turn shallow grooves on the piston skirts to ensure lubrication —as is done on TRW and Chevrolet forged pistons. Pistons can be glass-beaded inside and out if the ring grooves and pin bores are masked off. Rings will not seal if the grooves are beaded because this destroys the essential flat sealing surface. Beading adds oil reservoirs in the piston skirt.

Piston balancing—Any replacement piston for the VW will probably weigh more than the stock item which it replaces—especially if you are increasing the bore size. This is not a problem so long as all piston and pin assemblies weigh the same. The crankshaft, connecting rods, and flywheel and clutch should also be carefully balanced by a capable and experienced balancing expert. Avoidance of excessive piston weight improves engine life by reducing loads on the piston itself, pin, connecting rod, bearings, and the connecting-rod bolts. Material should not be removed from the slipper or load-bearing portion of the skirts or the pistons will be seriously weakened. Balancing pads are provided to permit equalizing the weight of all pistons in a set.



Bill Clarkson's Iguana hustles through the 1/4 mile in 12.09 seconds at 108.30 MPH. Engine equipped by Competition Engineering features their specially ported heads. Cam lifts 40 mm intake valves 1/2 inch off of radiused seats. Crank is SPG roller, Litz-modified for reliability and oiled from full-flow filter system using a modified VW stick-auto oil pump. 95 mm forged pistons live in special fin-less cylinders. Carbs are 48 IDA Webers. Engine photo by Ray Litz.



STOCK CYLINDERS—DON'T TRY TO BORE 'EM

Boring stock cylinders oversize is more difficult than it first appears because most shops do not have correctly made jigs to hold the parts to insure straight, round bores. As a result, clearances may vary over the length of the cylinder. Burned or stuck pistons inevitably result from incorrectly bored cylinders. VW grooves the outside of the 1200/1300/1500 cylinders at the head end so it is literally impossible to bore these any further. If you need a replacement cylinder—buy one from the VW store. If you want an oversize bore, buy special parts.

Words of warning—some oversize cylinders (including stock ones) can be installed without machining the crankcase halves, others require machining only the cylinder heads—and still others require machining both the heads and the crankcase. If the cases have to be machined, then the engine must come apart, which I recommend with any new piston/cylinder combination. If you don't take the engine apart, there is no way to check the rod/piston alignment. Putting new pistons and cylinders onto an engine without this important step is wishful blundering because you cannot be positively sure that the pin holes in the new pistons are perpendicular to the cylinder axis, nor that the pin holes are really parallel with the pin bushing in the rod or with the connecting-rod journal of the crank. Also, the rod bores may be twisted in relation to the crank journal and piston-pin bore. When you add up all of the possibilities, the only prudent thing to do is to disassemble the engine completely and do the job correctly by aligning every piston/pin/rod assembly.

If you have ever torn down a factory-rebuilt engine, you may have spotted the 0.020" oversize pistons, rings and cylinders which these usually include. Such oversize parts are available at the VW store—but you may find a slight delay because the smaller dealers won't carry them in stock.

REPLACING LESS THAN A FULL SET OF PISTONS

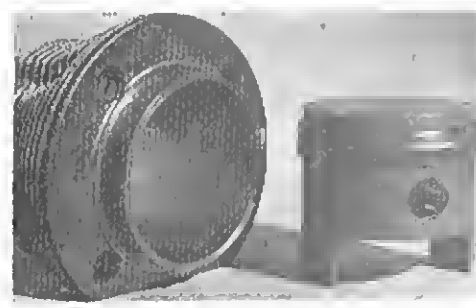
Replacing a piston in an engine is not a quick and easy job, even if you buy genuine VW parts. It's even tougher if you buy non-genuine replacement parts. Piston weights may vary from set to set. If you replace the connecting rod, that's still another weight to consider. Compression heights also vary. Cylinder lengths vary. When you add all of the possible ways that things can go wrong, replacing a piston and cylinder and/or a connecting rod can be a lengthy undertaking which can require completely rebalancing the engine parts unless you have an accurate record of what went into the engine in the first place: connecting rod total weight, big-end weight and small-end weight, piston type and weight (with pin), and cylinder length.

BIG-BORE PISTONS

Big bores are expensive—Increasing the displacement of your VW is not cheap. But, as the speed-shop sign says, *"Speed costs money—how fast do you want to go?"* Add up all of the costs carefully before going all-out on increasing displacement with special parts. Don't forget machining costs on the case and head when these are part of the installation procedure. And include the cost of a special sump, oil cooler and oil-temperature gage if you'll be driving where ambient temperatures climb into the 90°F area.

82 mm and 83 mm piston/cylinder sets for 40 HP VW 1200's - These German-made die-cast Kolbenschmidt or Mahle pistons operate in cast-iron cylinders. They have a compression height which is correct for the 40 HP VW 64 mm crank and the 40 HP connecting-rod length. The 82 mm bore increases the compression ratio from 7.0 to 7.5:1 and the displacement to 1351 cc. The 83 mm bore increases the c.r. from 7.0 to 7.9:1 and the displacement to 1385 cc. with the stock 64 mm stroke. No machining of crankcase or cylinder head is required for installation. The pistons and cylinders usually give 0.060-inch deck clearance as supplied. Both domed and flat-top pistons are offered in these sets, but you'll want to get the flat tops because they will run better. Replacement rings are available from EMPI, Grant, Deves and ATE dealers. Pre-1967 1500 rings will fit the 83 mm pistons. EMPI's are flat-top pistons made by Mahle and they have 1.5 mm compression rings for the ultimate in oil control. Some Kolbenschmidt compression rings are 0.102-inch wide and the oil rings are 0.160-inch wide; others have 1.5 mm compression rings. Replacement rings for both types are available from ATE, Deves, EMPI and Grant dealers.

VW 1200 (40 HP) owners are often excited by the large displacement figures which they see quoted for VW engines. But, the amount of displacement which you can tack on to one of these engines is limited by the fact that the cylinders are shorter (due to the shorter 64 mm stroke) than the later ones. It might seem tempting to install the larger stock or big-bore assemblies designed for the 1300/1500/1600 engines—or even the stock 1500 or 1600 cylinder/piston assemblies—but it is not economically feasible. If you were to install cylinders designed for the larger engines, it would be necessary to replace the connecting rods, use longer studs, and replace all of the sheet metal parts, heater boxes, etc.



83 mm Kolbenschmidt pistons and cylinders for 40 HP engines are available with both thick and thin compression rings. Thinner 1.5 mm compression rings are best for high-rev applications. Thick rings pictured on this set.

Inside view of 83 mm Kolbenschmidt piston for 40 HP shows K superimposed over S trademark, backside of slotted oil-ring groove, and cast-in steel anti-expansion ring.

In short, the gain in displacement is not worth the extra cost. If you want to build a "big" 40-horser—see the details in the crankshaft chapter on how to get 1602 cc's at a fairly reasonable cost.

So, if you own a 1200 engine, the 82 or 83 mm "big-bore" piston and cylinder sets are an inexpensive and efficient way to get some satisfying extra horses at very little cost—usually less than you'd pay for a new set of stock-bore pistons and cylinders from VW.

These piston and cylinder sets are guaranteed to "wake up" your 40-horser, even if you don't do anything else to it. And, they will make the engine perform just that much better if you are bolting in a cam or adding carburetion, etc., because the bigger displacement automatically ups the compression to 8.0:1. These cylinders can be used with stroker shafts if the cylinders are installed on spacers which are 1/2 the thickness of the added stroke. Refer to the crankshaft chapter for more details.

If you want or need more displacement, start with a bigger engine and you'll end up spending less money for the project.

Old-time VW hotrodders from way back to the early 60's will possibly remember that Competition Engineering in Pasadena, California was a pioneer in the VW competition scene with their adaptation of Corvair cylinders to the VW 1200's. The pistons are over 87 mm bore (3.4375-inch) and the 1964-69 Corvairs have a 1.59-inch compression height (center of pin to piston crown) which makes them easiest for use for such adaptations. Fin milling for clearance between the cylinders and to accommodate the studs was part of the job. The VW rods had to be honed to accept the 0.800-inch-diameter Corvair pins and the pins had to be fitted with aluminum or Teflon pin buttons to center the pin in the cylinder. Heads and case were also machined to fit the cylinders. This bore, in conjunction with a 69 mm stroke, gives 1660 cc displacement, or 1540 cc with the 40 HP stroke.

Ray Litz, President of Competition Engineering, says that the lack of demand for this sort of machine work on 40 HP engines makes it too costly to do, especially now that big-bore cylinders specifically designed for the stronger 1300 and larger VW engines are readily available for less cost.

85.5 mm piston/cylinder sets for 1300 & 1500 VW's—These die-cast Mahle and Kolbenschmidt pistons operate in cast-iron cylinders. They have a compression height which is correct for use with the 69 mm stroke crankshaft and the 1300/1500/1600 connecting-rod length. They increase 1300/1500 displacement to 1584 cc. This is the stock bore size for the VW 1600, so these pistons and cylinders are available as replacement parts or as genuine VW stuff from the VW store. However, genuine parts are usually more expensive than the replacement parts. When these pistons are installed in the VW 1300 engine, the cylinder heads must be bored to accommodate the upper end of the cylinder. Deck clearance is usually 0.060 to 0.070 as supplied. Replacement rings are easily obtained from TRW, Grant, EMPI, Deves or ATE dealers.

87 mm & 88 mm "no-bore" sets for 1300/1500/1600—Sets which install without boring the case or heads have the same oil-control and distortion problems as the 92 mm cylinders mentioned later. The cylinder walls are too thin to maintain rigidity under heat and loads. The cylinders are so thin at the head sealing surface that breakage has been reported in many instances. Compare this thickness with that of a stock cylinder or a Kolbenschmidt 88 cylinder and you'll see the problem. Add to this the fact that the pistons are extra-heavy (about 100 grams more than a KS 88) with dished-in tops and you'll get the picture—these pistons are for mass merchandising to the unsuspecting public who don't know any better and probably couldn't care less so long as they could brag about having "big-bore" cylinders.

88 mm piston/cylinder sets for 1300/1500/1600 VW's—These die-cast Kolbenschmidt pistons operate in cast-iron cylinders. The engine must be completely disassembled to install these pistons because the crankcase and cylinder heads must be machined to accommodate the larger cylinders. These are the most popular and most widely available big-bore pistons and cylinders. An "R" in the part number indicates clearance under the pin bosses for use with an 82 mm roller crank. The pin location (compression height) gives 0.060 to 0.070-inch deck clearance with the stock 69 mm stroke. Spacer-ring calculation for other strokes is discussed in the crankshaft section. Replacement rings 2mm (0.079 in.) compression, 5mm (0.197 in.) oil are available wherever Deves or ATE rings are sold.

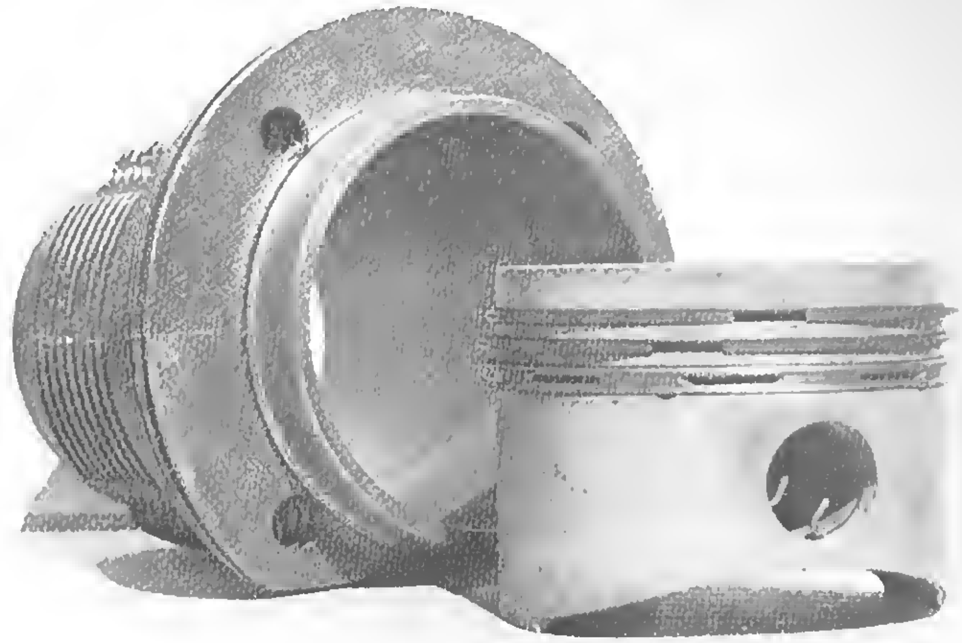
88 mm and 88.75 mm slipper-skirt pistons—TRW's forged L2206F pistons for 1964-69 Corvairs can be used in 88 mm cylinders. The 3-7/16 + 0.030-inch pistons are within a couple of thousandths of 88 mm and the 1.578-inch compression height is just 0.031-inch taller than an 88 mm Kolbenschmidt piston for the 69 mm stroke. This difference can be taken care of when you bush the connecting rod to accommodate the 0.800-inch-diameter Corvair pin. Machine the bushing with approximately a 0.031-inch offset for the 69 mm stroke. Longer strokes can be accommodated with spacer rings as detailed in the crankshaft chapter, and the bushing can be offset in the opposite direction so as to get a longer rod center-to-center spacing—and therefore, more favorable rod angles. These pistons have no provisions for pin locks, so pin buttons must be machined to center the pin in the piston. The pin bosses will have to be machined to widen the space between them for use with SPG roller cranks, or else the rods will have to be narrowed at the small end to provide the correct clearance. See details in the crankshaft chapter.

Two 1/16-inch compression rings are used in conjunction with a 3/16-inch rail-type oil ring setup which lives in a slotted groove. When you install these pistons, the arrow must point to the crankshaft pulley instead of towards the flywheel because Corvairs rotate oppositely to VW's. Some honing of the 88 mm cylinders will probably be required to get the desired clearance.

If you have a set of 88 mm cylinders which are badly scored or worn, consider using the L2206F 3-7/16 + 0.060-inch pistons. This works out to about 88.75 mm. The pistons cost about $8 each at TRW dealers.

92 mm pistons and cylinders—American-Kal Enterprises imports these die-cast aluminum pistons and cast-iron cylinders from NPR, a Japanese manufacturer, and sells the sets through several distribution channels under various names. Compression heights are available to fit the pistons with 64 mm, 69 mm and longer strokes through 82 mm. Individual piston molds have not been made for each of the strokes, so some of the strokes are accommodated by reducing the thickness of the piston crowns. Some performance-oriented shops substitute forged pistons because the die-cast pistons are apparently prone to ring-land breakage. This breakage is probably aggravated by the super-thick rings which are used (0.090-inch compression, 0.155-inch oil). Substitute pistons should be Crown's custom made TRW forgings with drilled oil-return holes in the oil-ring grooves. But, the forged pistons will not overcome the distortion tendencies of the thin 92 barrels.

Several changes have been made in both the pistons and the cylinders since they were introduced in 1969, but none of the changes correct the basic distortion problems of a cylinder which is too thin and has insufficient fins. Oil control and freedom from blowby at high RPM may be less than you'd prefer. Further, although many builders argue with me about this, opening the crankcase and heads to install the heads *weakens these parts so that cracking can and often does occur.* The minimum shelf for the cylinder bases is a mere 1/16 inch.



Kolbenschmidt 88 mm piston and cylinder. Piston is die-cast. This is most popular big bore setup because of its low cost. Rings are far too thick for racing use, but will work on street machines which only see an occasional stop-light Grand Prix.

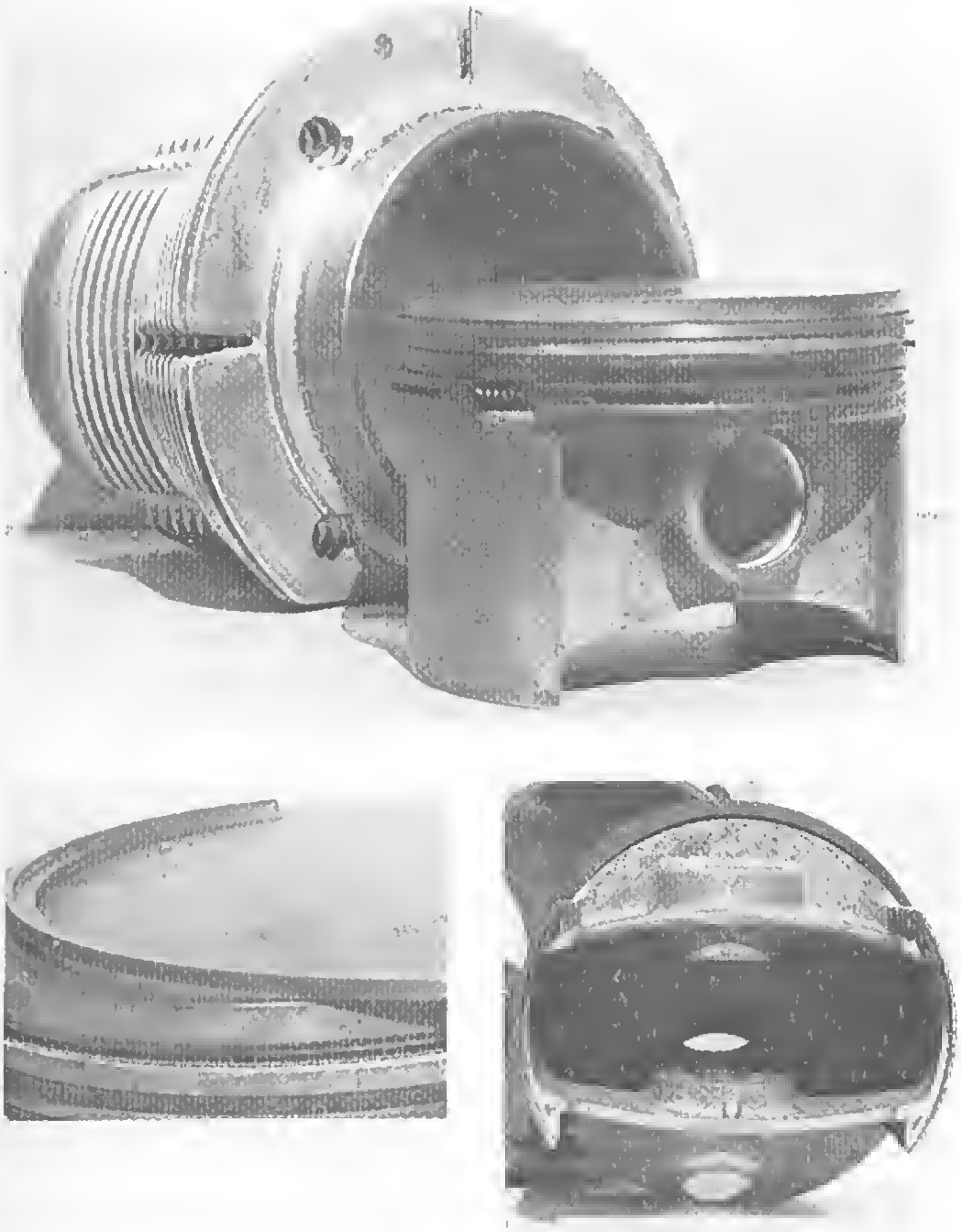
EMPI/MAHLE FORGED PISTONS & BIRAL CYLINDERS

Biral Cylinders—When EMPI President Joe Vittone approached Mahle, world-famous German piston manufacturer, to make EMPI 88 mm cylinders and pistons, they insisted that 88 mm was the largest practical and reliable bore size which could be used successfully. They further insisted that the cylinders had to have aluminum fins to get rid of the extra heat generated by the larger-displacement engine. The success of these cylinders in VW racing engines since 1966 certainly indicates that Mahle's expertise was expertly applied to the design. Die-cast fins on cast-iron cylinders allow the cylinder to stay round and provide excellent oil control under the most difficult racing conditions. The same kind of cylinders are used on Porsche 911 and 912 engines, so Stuttgart engineers like the idea, too. These cylinders are supplied in sets with either the slipper- or round-skirt 88 mm forged Mahle pistons as listed in the following descriptions. Machining the heads and case is required to install the cylinders.

88 mm slipper-skirt pistons—These are the *ultimate pistons* for high-performance VW's (as of the end of 1970) because they incorporate all of the features usually sought after for racing purposes. Empi has Mahle forge them with slipper skirts connected to the pin bosses by barrel-contoured supports for best strength. Upper-compression rings are 1.5 mm (0.059 in.) Dykes type for posi-positive sealing at high RPM; second compression is a normal 1.5 mm cast-iron ring and the oil-control ring arrangement measures 5 mm (0.297 in.).

The distance between the pin bosses allows use with narrower connecting rods on EMPI/SPG special 82 mm roller crankshaft. When used with other SPG rollers, the pin bosses may require machining for correct rod guiding. See the crankshaft chapter for more details.

NOTE: Dykes-type rings are not recommended for street or low-RPM use. EMPI may offer these sets with normal rings if there is sufficient demand, or you can have the pistons converted for ordinary non-Dykes-type rings.



EMPI/MAHLE 88 mm Biral cylinder with forged slipper-skirt piston. Dykes ring in top compression groove, thin ring for second compression, expander spring behind oil ring. Underside view of piston shows barrel construction joining slipper skirts to pin bosses.

You may find that these pistons give less than the desired amount of deck clearance. Equal numbers of Corvair cylinder gaskets (steel) as spacers under the cylinders can be used to increase the deck clearance. These are Chevy P/N 3832820 (0.013-inch thick, approximately).

EMPI offers the pistons, pins and rings for $29 each separately for VW builders who already have 88 mm cylinders. The pistons come in 88 mm and 88.5 mm sizes only. Complete sets of the pistons, pins, rings and BIRAL cylinders are $290.

88 mm round-skirt pistons—These EMPI/MAHLE forged pistons are the original big-bore pistons for the 1300/1500/1600 cc VW engines. They were first introduced in 1966 and supplied with the BIRAL cylinders. The pistons are offered only in 69 mm stroke compression height. These pistons provide about 0.050 to 0.055-inch deck clearance with no gasket under the cylinders. Calculation of spacer-ring thickness for longer strokes is discussed in the crankshaft section. Ribs inside the skirts provide extra strength in the load-bearing areas. Ring set up is 1.5 mm (0.059 in.) each for the two compression rings and 5 mm (0.197 in.) for the oil ring. Use of the pistons with a standard SPG roller crankshaft may require spacers at each side of the rod small end for correct rod guiding. See details in the crankshaft chapter.

Price for the pistons, pins, rings and BIRAL cylinders in complete sets is $250.

BORING THE CASE AND HEADS

Flycutting heads is discussed in the cylinder-head chapter. Machining heads to accommodate larger-than-stock cylinder bores must be accompanied by similar machining on the cylinder openings in the crankcase halves. This work is best accomplished in a milling machine. Ray Litz of Competition Engineering regularly does it on a Bridgeport Mill for $40 for a case and two heads.

However, because milling machines are expensive and take a great deal of time and experience to set up and operate, Gene Berg developed a $140 drill-press-driven tool for flycutting VW heads and boring heads and cases. EMPI also has a $295 hand-operated tool (TCHX-270) for increasing the bores in the heads and cases. While these tools might seem to be high priced, you could get your investment paid back almost immediately by machining the gasket surfaces of cylinder heads for VW specialists and dealers in your area . . . because that's all that is needed to save many heads which have been scrapped.

When boring the case for use with larger cylinders, there's no need to provide any more than stock clearance between the outside of the cylinder spigot and the hole in the case. About 0.010 inch is fine. The same clearance works well with the heads.

Ray Litz says, "It has been our experience that too little clearance here does not pay off in the long run, especially on race engines which may be frequently disassembled. Warpage and varnish deposits will freeze the cylinders to the case so tightly that the cylinders may have to be destroyed to remove them. This is why stock cylinders are stepped at this point. We employ 0.010/0.015 clearance to avoid this problem."

The shape of the cutter used for boring out the No. 3 cylinder spigot in the case is especially critical. It must have at least a 1/32-inch radius on it so that the bottom of this spigot will not have a sharp "corner" to provide a starting point for cracks. This is a weak point in the VW case—cracks start from here even with stock cylinders. Larger cylinders don't help the problem to get any better. This bottom "corner" of the bore nearest the flywheel can be polished smooth with a Cratex tool to insure that there are no stress risers to cause cracks. During the trial assembly of your engine you should check to make sure that the No. 3 piston at BDC does not bottom against the bottom of the bored-out step in the case.

As a further aid to reliability, Dean Lyon suggests that this area be heliarced after preheating the case, keeping in mind that the case will undoubtedly have to be lapped and line bored afterward, or at least the No. 1 main saddle bored for an oversize bearing.

Typical Measurements for Boring Cases and Heads

Cylinder Type	Case	Head
85.5 mm VW 1600	3.552	3.365
EMPI 88 mm BIRAL	3.635	3.769
Kolbenschmidt 88 mm	3.650	3.805
92 mm	3.792	3.885

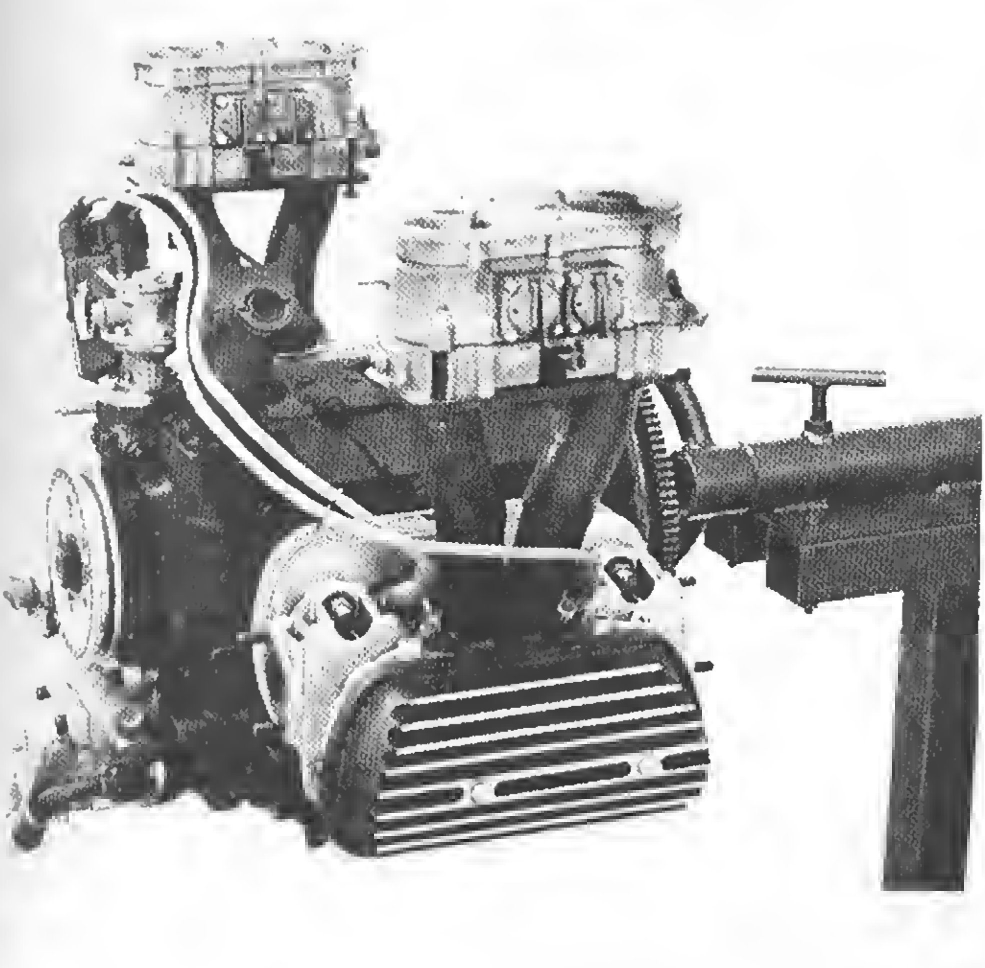
Mike each of the cylinders at top and bottom, then be sure that head and case openings provide no more than the recommended 0.005-inch clearance. Don't assemble the engine to run until any tight fits have been corrected or you can expect hard starting and perhaps scuffed or even stuck pistons.

HONING CYLINDERS FOR CLEARANCE

Cylinders should be clamped in a holding fixture which secures the cylinder similarly to the way it is held when it is installed in the engine. The holding fixture—not the cylinder—can then be clamped in a vise or onto a bench so that the hone can be run in and out of the cylinder. It is important to keep the cylinder cool by wrapping a wet rag around it and taking care that the hone is not run hard or long. If the cylinder is allowed to get warm or hot from the honing, the chances are good that the hon ing job will give you a cylinder which is neither round nor straight. When the hon ing job is finished, wash the cylinders firs in solvent, then in soap and very hot wat with Comet, Dutch Cleanser, Ajax or a similar detergent-laden abrasive cleanser. Keep washing until you can guarantee yourself that the cylinder pores have bee thoroughly cleansed of all of the honed-off particles and pieces of the honing stones. Dry the cylinder and immediatel wipe it with a lightly oiled clean rag. Wra the cylinder in a sack or poly bag to keep it clean until you are ready to install it.

Apply *thin coating* of flat-black paint or black stove paint to the exterior surfaces of the cylinders. This provides the best possible heat transfer from the cylinder fins to th cooling-air blast. Actual tests of this blac paint idea show that it reduces cylinder

Cracks in the left case half are not uncommon when it has been bored for the installation of oversize cylinders. Crack extends into main oil gallery, making this a junk case. We've even seen this crack with stock cylinders.



ACE Super Vee engine is equipped with ACE heads, dry-sump system and manifolds. A single Autolite four-barrel carburetor cut in half makes two carbs shown here. HP chart showing engine development is on page 38.

88 mm die-cast EMPI piston with aluminum-finned cast-iron cylinder. Compression rings are 1.5 mm width. Made in Japan by same firm which die casts Honda Grand Prix car and motorcycle pistons.

running temperature at the hottest point by as much as 80 degrees Fahrenheit. Thus your oil has less cooling to do, giving your engine the added benefits of increased bearing life. Incidentally, avoid any paint claiming insulating qualities, such as VHT ENAMEL which is perfect for exhaust components. In this instance you want to let the heat out of the cylinders, not keep it in. VW Speed & Sport's Don Baker claims that Vees work best with soft cast-iron rings such as Grant's, although other builders use a Dykes-type top compression ring and others prefer the Deves rings. Don says, "The secret in making the stock engine turn high RPM lies in the ring-to-cylinder-wall seal. For racing, a soft ring provides a quick seal – and a better seal. Even a tiny bit of dirt in the engine can break this seal, causing considerable power loss. The best way to get the seal is to hone the jugs with 600 emery paper by hand or in a lathe—slowly —until they are glass-smooth. It's easy to tell if you've gotten the seal right because the rings seat almost instantly. You can check by warming the engine up for a few minutes and then pulling one of the exhaust flanges. The color of the exhaust port should be a white/gray. If it's black—you lose—start over again!"

PISTON-TO-CYLINDER CLEARANCES

Application	Clearance (in.)
Stock	0.0016 to 0.0023
Hot road machine	0.003 to 0.0035
Street/strip racer	0.004 to 0.005

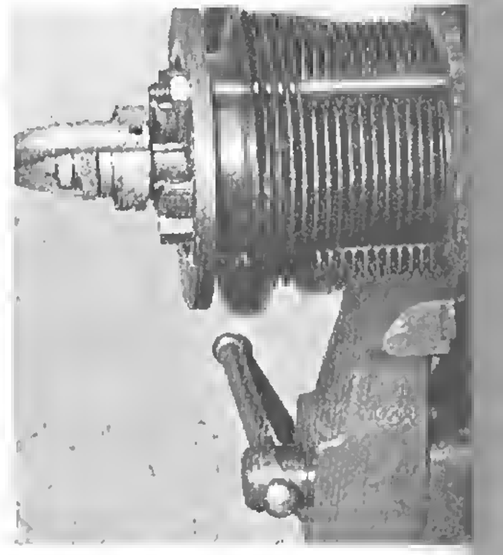
NOTE: When cylinders are worn to 0.006 or 0.007-inch clearance, rings are difficult to "hold," and ring lands begin to wear rapidly. Such clearance may be o.k. for all-out drag applications where the engine never has a chance to warm up and where the cost and frequency of replacing pistons and cylinders is expected as part of the price to be paid for going fast.

Clearances listed are based on the assumption that the engine has adequate cooling and that it is being operated with the correct mixture and spark advance. If carburetion is set up too lean—or if there is too much spark advance—pistons will stick and you can count on buying new parts. This brings up another important point. Replacement pistons and cylinders are not always available in broken sets. That is, you may have to buy a full set when you one need one piston. Keep this in mind and buy from the dealer or manufacturer who will agree to sell you just one piston and/or cylinder should you ever need it. In this instance I am talking about standard replacement pistons—including big-bore types—but not custom-made pistons. In the case of custom-made pistons you will usually find that you can buy as many as you need, with the usual delay for delivery. For that reason, dyed-in-the-wool racers always get from one extra piston to as many as a complete set, complete with rings so that they will not be torn down waiting for parts when an important race is coming up.

WHAT TO WATCH FOR WHEN INSTALLING PISTONS

Several items need attention when installing new or used pistons:

1. Piston-skirt/cylinder-wall clearance measured on the bottom of the piston skirt at right angles to the piston pin. Clearance must be suitable for the type of use to be given the engine, as detailed in the accompanying clearance table.
2. Clearance between the piston skirt and the crankshaft and the opposite connecting rod as the engine is turned. Clearance must also be provided between the bottom of the cylinder spigot in the crankcase and the bottom of the piston at BDC.



Honing cylinders for more clearance requires using a fixture such as this. Actually, four hold-down bolts should be torqued to actual values used for installation to simulate distortion created when the cylinder is installed in the engine. It's important to keep flushing the grit away with solvent. Do not let hone friction heat the cylinder—go slowly.

3. Deck clearance: The distance between the flat part of the combustion chamber and the piston at Top Dead Center. Deck clearance should be measured when the engine is assembled and the heads torqued onto the cylinders, or with the cylinders held down with spacers. Details are in the engine-assembly chapter.
4. Alignment of the piston/pin/connecting rod assembly to insure that the piston will travel straight in the cylinder. Each assembly must be aligned.
5. Balance: All rods should have the same total weight, big-end weight and pin-end weight. All pistons should weigh the same when checked *with their pins and ring assemblies.*
6. Offset location: Offset piston pin must be installed so that the pin is closest to the bottom of the left cylinders (3 & 4) and is closest to the top of the right cylinders (1 & 2) when looking at the engine from the crank-pulley end.
7. Rod offset at pin end: Rods must be installed so that the forged mark on the rod shank is upwards when the rod points to its cylinder.

From this list of "musts" you can see why it is essential to have a Service Manual at hand when working on the VW—otherwise you will waste hours and hours trying to get parts assembled on a

guesswork basis. Interestingly enough, VW's pocket-size handbooks for their mechanics are entitled *Without Guesswork.*

Cylinder base gaskets - Don't use 'em unless you can get metal ones—which are helpful in setting deck height. All you need is gasket-sealing compound between the cylinder base surface and the crankcase. Paper gaskets should not be used because they can squash out under the holding pressure—causing oil leaks. And, it is all too easy to break them during installation, which causes the same problem. Permatex Aviation Form-A-Gasket No. 3, Gasgacinch or RTV are recommended sealants.

Ring gaps - Don't line them up—position the oil-ring gap upward with the compression-ring gaps at 45° to the right and left, respectively. This lets you see all of the gaps as you install the cylinder. Go slowly and easily—have another person watch the underside of the cylinder to make sure that a ring does not slip out between the ring compressor and the cylinder. If a ring slips out, it is possible for the cylinder to be installed anyway because ring lands break easily and the cylinder will slide right on without your knowing that damage has been done. *Be careful.* Such an occurrence is a major disaster because you won't find out about the problem until you get the engine on the dyno or back in the car.

PISTON RINGS

Piston rings are always a subject of interest among auto enthusiasts. This is because they are almost always replaced during engine rebuilds and must, of course, be replaced if the bore size is changed. Although few mechanics hesitate to debate the merits of various brands of piston rings, many do not understand the basic functioning of these vitally essential parts.

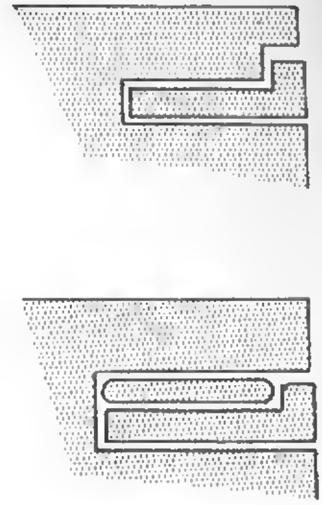
The sealing of combustion and compression pressures occurs as these same pressures enter the ring grooves, forcing the rings down against the bottom of the grooves and outward against the cylinders. Although outward stresses are built into the rings, these merely *assist* the gasses in sealing. Ring pressure against the wall does not accomplish much sealing. Tests made by Ricardo showed that rings operating *without* gas pressure behind them failed in a few minutes of operation.

Racing-engine builders frequently talk of "ring flutter." At high RPM the top ring may have sufficient inertia as the piston decelerates near TDC, so that it is held against the top of the ring groove. Gas behind the ring escapes to the crankcase and the top ring collapses *inward* under cylinder pressure, instead of being pushed outward as in normal operation. This results in vastly increased blow-by which pushes oil out of the crankcase, and drastically reduces power output. Ring collapse or "flutter" occurs only on the power stroke and always causes ring breakage if allowed to continue.

Designers of modern high-performance, high-RPM engines avoid ring flutter by reducing compression-ring width, thereby decreasing their weight and consequent inertia. Ricardo's famous book says, "Taking all of the arguments into account it would seem that the width of the ring should depend on the normal speed of the engine; the higher the speed, the narrower the ring." As proof of this comment we see high-speed two-cycle engines such as racing outboard and motorcycle engines using 1/32"-wide rings to prevent flutter at speeds which may exceed 10,000 RPM.

When you look at the thick rings on some of the pistons being sold as VW high-performance equipment you would think that you were back in the late '30's or early '40's.

Any compression ring thicker than 1/16-inch or one-piece oil rings thicker than 1/8-inch are probably too thick to provide any oil control whatsoever in a high RPM VW engine. Rail-type oil ring setups which are combinations of very thin rings with wavy spacers can be wider, of course. If you have pistons with wider ring grooves, you might investigate Perfect Circle's spacers which allow using thin rings in wide grooves. Don't waste your time trying to build huge breather boxes to contain the oil from a bad blow-by condition. You will be way ahead horsepower-wise by eliminating the blow-by problem through the use of the correct rings. Using the correct rings becomes especially important when you are using a roller crank because these cranks will (1) permit more RPM's and (2) because the crankcase is literally filled with the oil mist which is sprayed out from the jet grooves in the bearing shells.



Above, Dykes ring in stepped groove. Below, Dykes ring in ordinary groove with spacer adapter ring.

A trend began to grow very fast in 1963-64: racing-engine builders turned to a 20-year-old idea to solve their ring-flutter problems on big-bore high-horsepower engines. They began installing an L-shaped ring invented by Dr. Paul de K. Dykes of Cambridge University. These rings are used almost exclusively in high-performance engines. Even so, because the rings use low tangential pressure against the cylinder wall, cylinder wear may be reduced during those strokes when the rings are not pressure-loaded. Dykes-type rings require a special stepped groove or a spacer can be inserted in a standard, non-stepped groove to allow using them in a piston which was not originally machined for Dykes rings.

Chrome-plated top-compression and oil-ring rails are often used where cylinder finish can be controlled because these rings give better cylinder wear and resist corrosion. These rings seat quickly if the cylinder is round and correctly honed. Moly rings (cast-iron coated with molybdenum) are also widely used. Chromed and moly rings must always be examined carefully for chipped or damaged surfaces prior to their use or reuse. Such defects cause serious cylinder-wall gouging if run in an engine. Even new factory-fresh chrome rings are sometimes chipped. When re-ringing an engine it is important that you use non-chromed cast-iron rings because the worn cylinders are no longer round. Chrome rings cannot

provide perfect sealing in worn cylinders because their hard surfaces do not readily conform by "wearing in."

Oil control is a separate subject. Dr. Dykes has also been responsible for research which proved that oil passes the rings in both directions and in large quantities. Although oil flows past the oil-control rings on the downstroke, it is returned to the sump on the upstroke. There are at least two types of oil-control rings to consider: (1) the type using two chrome-plated rails above and below a wavy ring separator, which probably should not be used for re-ring jobs, and (2) the dove-tail design slotted cast-iron ring with an expander.

Fitting Rings

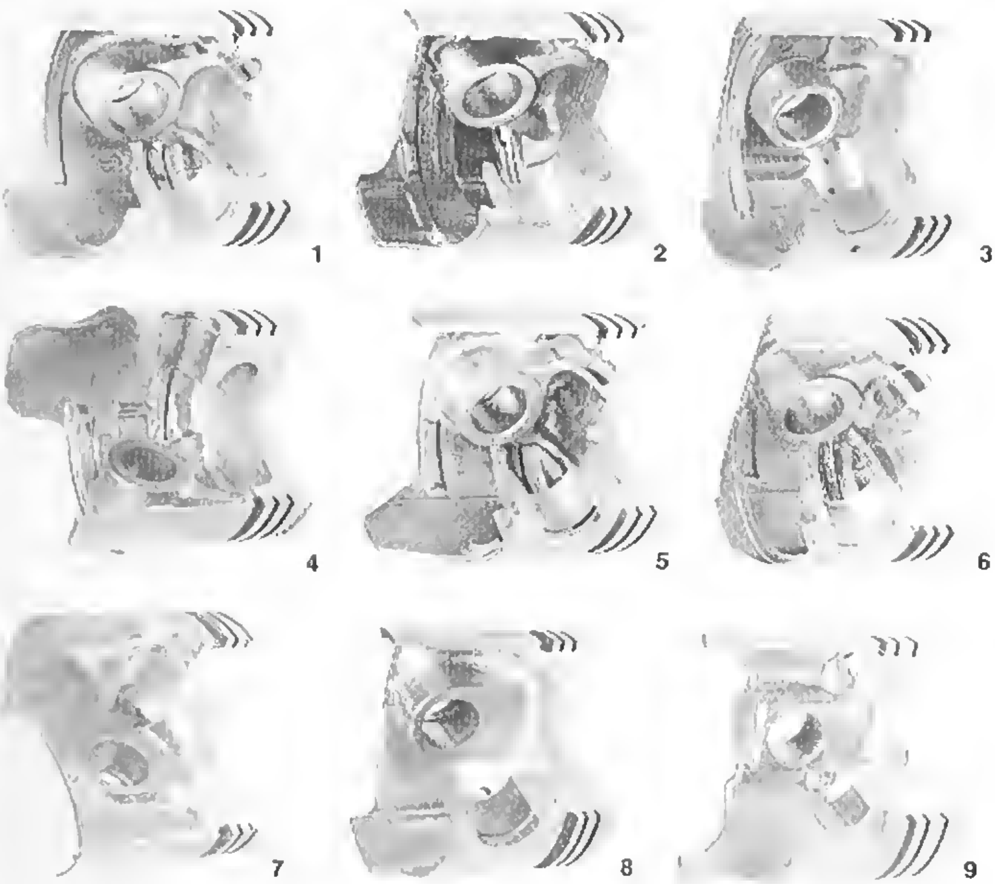
In addition to the usual dimensioning of the rings to fit bore diameter and ring-groove width, two other measurements are quite important: ring end gap, and groove clearance.

End gap is measured by pushing the ring squarely into the bottom of the cylinder about two inches with a piston. A feeler gage can be used to measure the end gap, which should be not less than 0.0045-inch per inch of bore. Example: For an 88 mm bore (3.504-inch), 3.5 x 0.0045 = 0.0158 -or 16-thousandths of an inch. It is better to err on the high side and get too much gap than too little. A gap of 0.016 to 0.020 is suitable for this bore size—and a gap of as much as 1/32" would not affect performance. End gaps which measure too small when the ring is installed in the cylinder can be opened up by holding the ring in a vise, protecting it with a cloth or cardboard, and carefully filing or stoning off the ends to get the desired gap. If your pistons arrive with the rings installed, don't be lazy—take them out and measure the ring gaps and the groove clearance as discussed herein and in the service manual.

Ring Grooves

Ring-groove condition is vital to the functioning of the rings. According to Richard MacCoon of Grant Industries, "Rings are just like valves and must have a good seat on which to seal. Groove finish is every bit as important as that of the cylinder or the ring itself. Piston makers machine piston-ring grooves with extreme care to ensure perfectly smooth surfaces. Yet you will often see 'mechanics' use a broken ring to clean out carbon from these finely machined grooves. They gouge and burr the groo and still expect the rings to work. Spe tools for reconditioning grooves should always be used when fitting new rings t used pistons."

Ring-groove clearance is als measured easily with feeler-gages. Ste piston-groove clearance for compressio rings should be from 0.0012 to 0.0032 measured between the ring and land. (ring clearance, measured between ring and land, should be 0.002 and 0.0035. Replacement and racing pistons often specify 0.002 to 0.004 clearance for c pression rings. Special groove clearanc are needed for Dykes-type rings. Ring groove clearances on the low side impr oil control and high-speed performanc but increase the risk of ring sticking in short period of time, especially where engine is used only on the street. Too much groove (side) clearance increases consumption, causes groove pounding, and finally ring breakage. Additional clearance can be obtained when neede sanding the side of the ring on a flat s face. Solvent-wetted Wet or Dry pape supported on a thick piece of glass wo nicely.



Cutaway pistons 1 through 6 are die-c construction and include cast-in steel expansion belts. 1 - VW 1500, 0.275" head. 2 - VW 1600, 0.187" head. 3 - M 92 mm, 0.245" head. 4 - Mahle 82 mm 0.290" head. 5 - Kolhenschmidt 83 m 0.296" ribbed head, thin rings. 6 - Kol benschmidt 83 mm, radiused under sk for roller-crank clearance, 0.323" ribb head. 7 - Mahle 88 mm slipper-skirt fo piston, drilled oil-return holes for stre 0.280" head, thin rings. 8 - Mahle 88 r round-skirt forged piston has drilled oi return holes for strength, ribs on insid thrust areas, 0.280" head, thin rings. 9 TRW 88 & 88.75 mm forged slipper-sk piston has oil-return slots, 0.340" ribb head, thin rings. This Corvair piston adapts to the VW; see text.

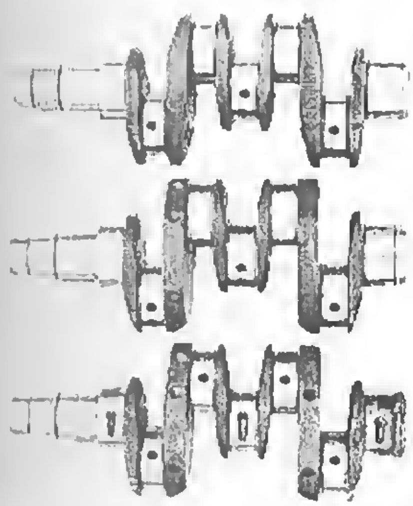
Crankshafts

a stock one works fine . . to 5,000 RPM

The VW crankshaft is a sturdy steel forging which has been heat treated at all bearing points by an induction-hardening process. It weighs 19 pounds. All of the main bearings are full-circle except for No. 2 which is a split bearing. Because the crank is only partially counterweighted, the No. 2 bearing gets the most wear due to crank vibrations—even when the crank is as near perfectly balanced as you can make it. Clutch thrust is taken at the front of the engine by a thrust bearing between the end of the crankshaft and the flywheel. Shims between the flywheel and crank end are used to adjust crankshaft end play. There are four main bearings. Nos. 1, 2, and 3 are 55 mm diameter (2.560 inches) and No. 4 is 42 mm (1.969 inches). Four 8 mm dowels 1/2-inch long locate the flywheel which is secured to the crank by a spring lock washer and a gland nut which contains the clutch-shaft pilot bearing. Removal of the crankshaft requires completely disassembling the engine. No. 3 bearing cannot be removed from the crankshaft until the crank gear is removed. The rear of the crankshaft mounts a pulley or an engine-cooling blower, depending on whether it is an "upright" or a "flat" engine. All of the crankshafts from 1961 1200 through 1600 models have the same diameter rod and main journals (55 mm). However, the stroke was changed from the 64 mm (2.52 inches) used in the 1200 and 1200A engines to 69 mm (2.72 inches) with the 1300 models. The 69 mm stroke is also used in 1500 and 1600 models, starting with an option in 1962 1500 bus engines.

Sometime during 1966 a running change was made to a flywheel with a deeper recess which spigots onto the crank. The crank is relieved for 0.365-inch. The shorter 0.165-inch relief on the early 66 and pre-66 cranks prevents use of the late O-ringed flywheels. However, the early gasket-type flywheels can be used on the late cranks with the longer relief—an important item to remember when swapping engines. End play must be reset and rechecked whenever a flywheel is changed.

Adding dowels on either of the crank flywheel styles requires the same procedure. As of 1967, crankshafts were improved by the addition of a second oil hole to supply each of the connecting-rod journals. Thus, each main journal contains two holes and each rod journal has two holes, allowing more oil to be pumped to the connecting-rod bearings each time the crankshaft revolves. At the same time, directional oil troughs were added to the crank's main journals. These increase the oil availability to the rod journals by providing a larger reservoir under pressure at the main journal itself because there is a longer area from which the lubricant can spread out.



Stock 40 HP crank (top) has thinner cheeks than 69 mm cranks introduced on 1300 models. Center crank is a 1966-67 without directional oil grooves, which were introduced in 1968 on "F" cranks. Lower crank with these grooves has been heliarc welded around No. 1 journal for wedge-mating to flywheel.

RPM LIMITS WITH STOCK CRANKS

VW engine life is drastically reduced when the stock crankshaft is used in an engine which is turned at high RPM's. As RPM's go up—engine life goes down! Continuous use of revs above 5,000 RPM, except for intermittent blasts up to 5,500 RPM maximum, cannot be recommended on the basis of tests which have been run for many years by noted VW experts. For this reason you do not want to build an all-out high-RPM engine based on the stock crankshaft. The use of revs above 5,000 RPM just beats out the case too quickly. If you tear down an engine which has been raced or abused with continual blasts up to high RPM's, you will find that the bearings have actually pounded their identification numbers into the crankcase bearing saddles. Furthermore, the case halves work back and forth against each other causing "fret marks" to appear on the surfaces.

Gene Berg made tests on one stock-crank engine by limiting the revs during acceleration to 6,500 RPM. After 2,500 miles, the case was so far worn that it had to be replaced. Then he tested another stock-crank engine with a limitation of 7,200 RPM and obtained 1,000 miles and 700 miles engine life on two successive tests.

Darrell Vittone has built numerous engines for EMPI GTX demonstrators and claims that he regularly gets 30,000 to 40,000 trouble-free miles, even though the tachometers occasionally see 6,000 RPM.

However, these engines are carefully blue-printed, align-bored if necessary, equipped with steel-backed No. 2 main bearings, and fully balanced. VW 131 105 531 or Glyco bearings have the steel-backed No. 2 main bearing. TRW's main-bearing sets are also steel-backed.

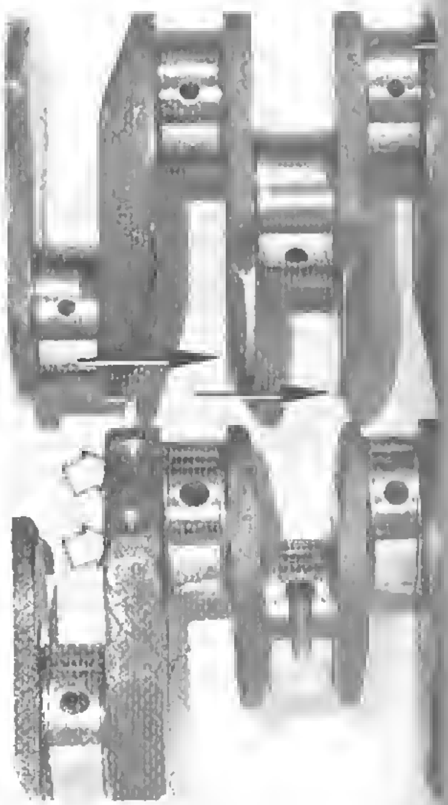
Hal Klieves of Race/Chek in Pompano Beach, Florida, says that even Super Vee engines with stock cranks must be limited to 5,500 RPM if you want the case to last through two complete racing sessions. Note that he is talking about racing sessions—not seasons! However, perhaps because of the lighter weight components and shorter stroke, he reports that the Vees manage consistent 6,000 RPM operation with little in the way of case problems.

On the other hand, Bob Wendland of ACE says that they get quite a few races and numerous dyno runs on some cases before the No. 2 mains show evidence of pounding out.

So, with these expert opinions buzzing 'round in your mind, here's my recommendation:

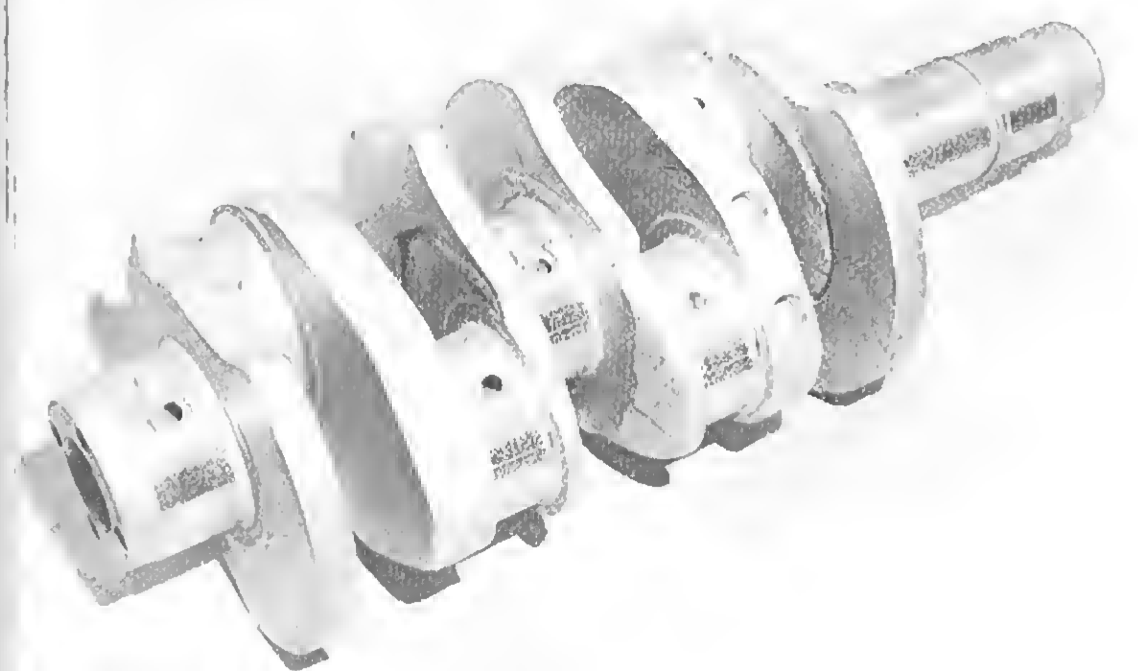
Build the engine with as large a bore as can provide the reliability required by your application. 88 mm works well for road or competition. Larger bores can be used, but the problems may offset the advantages. Balance all of the parts and limit the RPM to 5,000 RPM *with a rev limiter* such as Nu-Metrics' add-on for their digital tachometer. Don't trust an educated foot to keep the engine out of the high-RPM range. Install a counterweighted crank such as Gene Berg's if you need more revs. If you feel that a roller crank is your cup of tea, then be sure to limit the engine's compression to not more than 8 or 8.5:1 as the 1972 gasoline quality will not allow using higher compression without getting into some detonation. And, the aluminum cages used on the rollers deform when detonation occurs so that the first thing you know—*instant scrap metal!*—even though you may never have heard the detonation as it occurred. Incidentally, that rev limiter should be set at 7,000 RPM with a roller crank to keep within the limits set by the maker. Higher RPM can be used, but the engine life will be reduced as the limit is exceeded.

You've seen photos of Chevy V-8 cranks with welded-on counterweights. While these are not needed for the Chevy, such trickery can be a decided advantage for the VW. It's not a new idea for VW's because Joe Vittone, EMPI's President, was doing this when they first started racing VW's. But, the cost back in the mid-fifties was about $400 per crank from Hank the Crank. Bob Dickson worked out a way to add flame-cut counterweights to the VW crank and did quite a few through Gene Berg in 1971—then Gene took over the project and expanded the offering to include welded strokers up to 82 mm stroke *with Tuftrided journals* and correct heat treating to ensure long life. Berg's cranks are counterweighted, double-stress-relieved, Tuftrided journals, stroked, indexed, radiused, setup for late fly wheels, and equipped with eight dowels for holding the fly wheel. Price is about $400.



1968 and later VW crank (bottom) has three main journals grooved in direction of rotation. Outline arrows note factory balance marks. Stock crank has four dowels — not adequate for hotrodding. Okrasa counterweighted crank (top) has eight 8 mm dowels. Arrows indicate counterweights which reduce high-RPM flexing. These cranks are very scarce, seldom imported into U.S. anymore — and cost around $350 to $450.

Stock VW crankshaft photographed part of the way through the Berg remanufacturing process which adds counterweights to aid high-RPM reliability for racing engines.



NEED FOR STRAIGHT SHAFT

Although every part should always be checked for its dimensional accuracy, runout and so forth, it is easy to assume that the crankshaft—especially a new one from the VW parts bin—is straight. This is a terribly wrong assumption to make because new cranks are often found to be slightly bent. The crank can be laid in its bearings in one half of the crankcase and a dial indicator can be used to measure the runout of each of the main bearing journals as the crank is slowly rotated through several complete turns. The same test can be made by setting the crankshaft between centers in a lathe and turning it by

land as a dial indicator is used to measure each of the main journals in turn. If any journal deflects the dial indicator more than 0.001", the crank should be ground to the next undersize or replaced. If you are buying a new crank from VW, make an arrangement with the parts manager which will permit you to keep exchanging the new, unused crank for another one until you have found a straight one. The easiest way to do this is to bring your dial indicator and case to the parts counter and check the cranks right there—rather than carting them back and forth and getting everyone aggravated over what seems to them to be a trivial point. I can assure you that this is not trivial—it takes a straight crank to start with to get horsepower out of an engine. With the VW's tendencies towards pounding out the center main supports anyway, it is doubly important to start with a straight crankshaft . . . . so don't overlook this important factor when assembling your engine.

MODIFYING OIL TROUGHS & HOLES

Any stock crankshaft should be carefully deburred, even one which is brand-new and fresh from the dealer's stock bins. If you run your finger around the oil troughs and holes, you'll usually find sharp edges. These can ruin a bearing while you turn the engine over during a trial assembly. Deburr these holes very carefully with a fine abrasive wheel such as those made by Cratex. Run the wheel in an electric drill. Or, if you have a die grinder, be careful that you do not exceed the speed and overhang (length of tool extending from the spindle collet), recommended by the manufacturer.

Earlier stock cranks can be equipped with the oil troughs as shown in the accompanying photo. They can also be cross-drilled.

Do not groove either the main or the rod journals. This archaic practice greatly reduces the effective bearing area which is available to support the crankshaft and rods as they operate.

Noted automotive journalist Bob Waar points out that modifying the oil holes and adding troughs still does not alleviate the problem of the non-counterweighted crankshaft causing excessive erosion of the No. 2 main-bearing saddle.

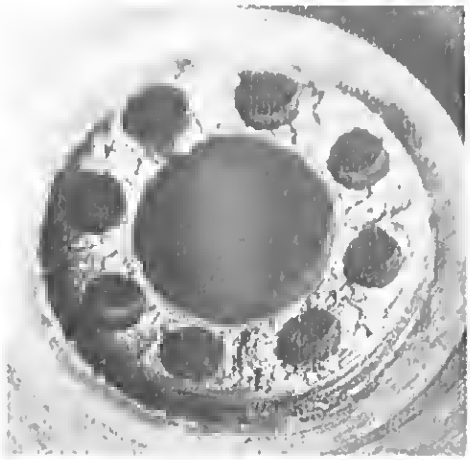
CRANK DOWELS

The following details apply to stock cranks and to welded stroker cranks. Dowel details for roller cranks are discussed later in this chapter in the section on roller cranks.

If there is a single weak spot in the VW as regards holding up to increased horsepower—it has to be the flywheel-to-crankshaft mating. The stock four 8 mm dowel pins will not, repeat WILL NOT hold the flywheel and crank together, even on an absolutely stock VW engine which is being raced. The pins are only 1/4-inch deep in the crank and the same in the flywheel. The engine revs too quickly for the flywheel to stay with the crank. The stock dowels tend to wobble back and forth as the crank and flywheel do their best to accelerate or stop at different rates due to the force applied to the flywheel by the pistons and resistance to that force applied by the flywheel's inertia and the clutch which tries to make the car obey what you are telling the engine to do with the throttle. Picture a fence post in soft ground. Wiggle the top of the post long enough and the hole gets so big that the post no longer stands upright. That's what happens to the stock dowels in the soft steel flywheel. Dowels wiggle around in the flywheel until you begin to hear terrible noises. Then it's too late! How do you know that this is happening? Well, your first clue is a "brrrt-brrrt" sound when you first rev a cold

Directional oil troughs can be added to the pre-"F" cranks with careful work. Sharp edges must be rounded off and the junction with the journal carefully polished so that the main journals will not be damaged. It is better to mask the journals.

engine. The noise is not affected by operating the clutch and the noise is worse when the engine is cold. When you hear this noise, park your car before you damage the flywheel and crank so terribly that both may have to be replaced. If you have assembled a VW engine and know about the 217 lbs. feet of torque needed to tighten that flywheel "gland nut," you may think that I am kidding about this. You can't imagine something that tight coming loose, can you?



Here's what happens when flywheel gland nut is not tightened to 217+ lbs. ft. or more. Even 8 dowels could not stop it from a bad case of the wiggles. Scratch one lightened, balanced and 8-dowelled flywheel . . . and probably the crank, too! Incidentally, this flywheel was "tightened" with an impact wrench.

The solution to the problem—and fortunately there is one, or you could forget about hotrodding your VW—is to pursue one or two fixes which were first discussed for the general public in an article describing Gene Berg's "VW Flywheel Gefixen" in the June 1969 Hot Rod Magazine even though Porsche has been using eight dowel pins since the first Porches were introduced. However, as of the time this book was published, Porsche engines were still being produced with very short 7 mm-diameter dowels which come loose with annoyingly expensive results. Seems that Porsche owners should take note of what VW hotrodders have done to solve the problem.

These fixes are "calibrated" to the horsepower which you expect from your engine:

65-85 HP	Add four more stock-diameter dowels, 8 mm diameter x 3/4-inch long.
86 HP and up	Change to eight 8 8 mm x 3/4-in. dowels or eight 11/32 x 3/4-in. dowels.

You'll need a drill fixture to install the dowels. Bill Taylor of Tayco offers one for \$60, EMPI has one for \$76, and Crown's \$35 one includes a drill and one set of 8 mm dowels. These may seem expensive until you stop to consider that you'll save more than the cost if you prevent problems on just one crank and flywheel. And you can use the fixtures to do cranks for other VW fans, too. The fixtures allow drilling an offset hole pattern to match SPG crankshafts, or evenly spaced holes if you prefer that pattern for a stock crankshaft. VW performance shops typically charge \$30 to install the dowels in a crank and make the matching holes in the flywheel. Incidentally, the dowels are about a buck apiece. If you are a machinist, making one of the drill fixtures is a simple project. Or, if you only have one VW flywheel and crankshaft to dowel, you could perform the entire operation without a special fixture, but then you could not switch components between several engines—that flywheel would always have to live with that particular crankshaft and there would be little chance that you could dowel either one to another part—that's the beauty of the fixture. Or, if you've purchased one of Crown's six-pound VW flywheels, the hardened center is a perfect drill jig in itself. It is drilled with the SPG-style offset-hole pattern. Use it for drilling your crankshaft to install the dowels. In fact, the flywheel comes with the 3/4-inch dowels and a high-speed drill.

First disassemble the engine so that you can work on the bare crank. Never attempt to add extra dowels in a crankshaft which is still assembled in the engine. However, if you are installing a Crown flywheel, no shims are used between the crank and flywheel *at the dowelled joint.* It is possible to install these flywheels onto a crank in an assembled engine, even with a hand drill—if you use a great deal of care. Of course, the crankshaft end play must be measured with the flywheel installed and reset as required with appropriate changes to the large-diameter shim pack. Use a dial indicator to make the end-play measurement.

1

2

3

4

5

6

Jim Herlinger, Lynx distributor in Mountain View, California demonstrates using TayCo's fixture to dowel a VW crank and flywheel. 1 - holding nut screwed into crank and two stock dowels still in place. 2 - crank supported in pulley as four new holes are drilled and two original holes are deepened. 3 - fixture located with two stock dowels as four new holes are drilled in flywheel. 4 - flywheel holes are deburred with countersink turned by hand. 5 - reaming through flywheel into crank with worn valve-guide reamer. 6 - installing new dowel pins into crank by using flywheel holes as guides. Holes in crank must be clean and Loctited, but avoid getting Loctite into flywheel holes.

By now you are glaring at the dowels and wondering just how you are gonna get those little turkeys out. There's not much sticking out to get hold of—and they are so hard that the vise-grips slip right off, don't they? Here again, Gene Berg has a no-sweat way to get dowels out. Just grab the dowel in a bench vise and apply a little vibration to the end of the crank with an air-operated rivet gun—or hit the flat end of the crank with a hammer. Out pops the dowel so easily that you'd better have a good hold on the crank if you don't want to drop it. Just take out two of the dowels because the other two locate the drill fixture or Crown's flywheel. Follow the directions! Watch what you are doing—you want the two stock holes to be perfectly registered with the fixture when you drop it on the two stock dowels. Now tighten the fixture in place, or use Crown's flywheel or center. Either provides one offset hole to match the hole pattern used in SPG cranks. The fixtures can be used to drill evenly spaced holes if this is desired, but for the purposes of this book, I'll only describe how to drill the offset pattern because it is the most widely used among VW enthusiasts.

VW has unwittingly provided you with the ideal tool for holding the crankshaft upright on your drill-press bench as you accomplish the drilling and reaming for the new larger dowels. They disguise it as a crankshaft pulley. Just slip one over the nose of the crank and there's your free holder—can't beat that kind of price for a super-neat tool! This is best done by one of your machinist friends with a drill press. I'd suggest dowelling at least one junk crank and flywheel before attempting to do it on new parts.

8-mm dowels - With the drill fixture fastened onto the crank, drill four 5/16-inch holes. Make the holes 3/8-inch deep for the stock 1/2-inch-long VW dowels, or 1/2-inch deep for the 3/4-inch-long dowels. Remove the fixture and deburr the holes with a flat stone, making a slight chamfer around each hole.

Transfer the fixture to your flywheel, using the two already-removed dowels to locate the fixture exactly as you had it on the crankshaft. Remember that the fixture provides an offset hole pattern. Drill four new holes in the flywheel with the 5/16-inch drill and remove the fixture. Install the flywheel on the crank, checking that the holes in the flywheel line up exactly with those in the crank. Chuck a worn 8-mm guide reamer in your drill press and turn it by hand so that it reams through the flywheel to the bottom of the four new holes. A valve-guide reamer is undersize at its end. You can mike across the reamer flutes to determine whether the reamer will provide a tapered hole with the correct interference fit in the crankshaft. The dowels should have a 0.002 to 0.003-inch interference fit at the bottom of the holes in a stock crankshaft, but not more than 0.0005 inch in an SPG roller or you'll split the crank! If the reamer end provides too much interference fit, the reamer can be shortened by grinding off the end of a point where it will cut the desired hole size.

When the holes have been reamed, put a drop or two of Loctite in each of the four holes and drive the dowels through the flywheel into the crankshaft, bottoming the dowels in the crank. Make sure that the dowel ends are slightly below the flywheel flange face. They must not protrude above this face or the gland nut and washer cannot do the required job of holding the flywheel in place.

If you are using the stock dowels, tap the flywheel off the crank and remove the two stock dowels from the crank. Clean the four holes and dowels and reinstall the original stock dowels with Loctite, driving them into the crank through the installed flywheel as this helps to cause the dowels to go straight into the crankshaft. Remove the flywheel and deburr its holes.

If you are using the 3/4-inch-long dowels, tap the flywheel off the crank and remove the two stock dowels from the crank. Reinstall the flywheel and drill through the flywheel and into the crank so that the four stock holes are deepened to 1/2-inch. Ream these holes with the 8 mm reamer as before, Loctite the holes and drive in the new dowels. Tap the flywheel off again and deburr its holes.

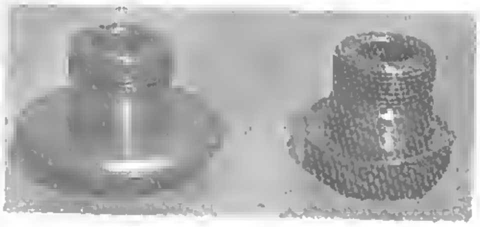
11/32-inch dowels - These are installed exactly like the 8mm dowels, including drilling with a 5/16" drill. However, when the flywheel is transferred to the crankshaft, an "R" drill and a worn 11/32" reamer are used instead of an 8mm reamer.

Why Deburr The Holes? Deburring is super-important when dowelling the flywheel/crank combination. If you fail to pay attention to this seemingly insignificant point, a raised edge around any one of the holes can hold the flywheel away from the crank far enough to permit a disastrous oil leak. If you have ever experienced oil on a clutch, you'll know what this can mean!

WASHER AND GLAND NUT

Two more items are required to ensure that the flywheel will stay where it belongs. First is a 0.150-inch-thick steel washer with a 2-1/4-inch outside diameter. It is chamfered to center on the flywheel. The stock washer is discarded because it merely covers part

of the dowels. The large washer covers all of the dowels and spreads the gland nut's holding force over a wider area to stabilize the flywheel against wobble.



Top: stock flywheel washer covers only half of dowels. More support for this vital connection is available through use of large-diameter, heavy-duty washer on modified stock gland nut. Stock gland nut head is turned off (transaxle side) 0.040 inch. Threads on nut and in crank must be cleaned carefully. 250 to 400 lbs. ft. torque is used with Loctite. Allow plenty of time for Loctite to set up before using the engine or use Locquic Primer.

The second item needed is a new stock VW gland nut, P/N 111 105 305 E, which should be machined off 0.040-inch (toward clutch). If the nut is not machined off, the clutch hub may hit it, thereby preventing the clutch plate from contacting the flywheel. Install the machined nut with the large washer, Loctite the threads of the nut and torque the nut to 350 to 400 ft. lbs. torque. Don't skimp on the torque because the nut will come loose if it is insufficiently tightened. Darrel Vittone suggests that the modified gland nut be torqued to at least 400 ft. lbs. But, before installing the nut and washer, he meticulously cleans the threads of the crankshaft and of the gland nut, then uses Locquic—Loctite's preparation fluid—and adds Loctite to the threads at the appropriate time. He also recommends allowing the crank to stand for at least two days before firing the engine so that the Loctite will have had ample time to set up.

WEDGE-MATING FLYWHEEL AND CRANK

With the swing to rear-engine mounts for the VW and the consequent reduction or elimination of wheel hop, Berg claims that the wedge-mating method (used on Porsche Carrera racing engines) is seldom required anymore, except to reclaim an expensive crank which was not equipped with the right number and size of dowels to start with . . . or which was run in an engine without a rear mount. The eight 11/32-inch dowels, big flange washer and late-model gland nut will get the job done—provided that you keep the rear of the engine supported so that it doesn't jump around when you sidestep the clutch at high RPM's on starting. He'll wedge-mate your flywheel and crank for $60, including the installation of eight new dowels.

CONNECTING RODS

Some 40 HP—and all 1300/1500/1600 (1966 and later) rods—have an offset small end to center the rod in the piston. A forging mark on these must face up as the rod points to its piston. Mid-66 rods, P/N 311 105 401B, have precisely ground bolts pressed into the caps to center the cap automatically as it is installed.

Never replace a single rod without balancing it for total weight and end-for-end with the others in the set. Replacements may be so different that they will "throw" your engine 'way out of balance.

ROD COMPARISON TABLE

ENGINE	PIN DIA.	LENGTH (mm)	LENGTH (inches)
36 HP	20 mm	129.25	5.086
40 HP	20 mm	130.	5.120
1300/1500/1600	22 mm	137.	5.396
Porsche	22 mm	136.	5.357

VIBRATION DAMPER

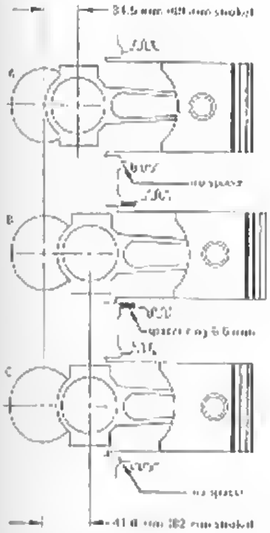
Vibration can wreck any crankshaft, the flywheel attached to it and the bearings in which it revolves. Vibration is caused by the inertial forces created by the connecting rods and other attached parts, by unbalanced pistons, rods, crankshaft, flywheel and crank pulley and by centrifugal forces. As the crank turns, its rod journals are alternately subjected to forces of up to a ton on the power strokes. These forces try to twist that journal ahead of the rest of the crankshaft—instantaneously. As

Rear of crank with elongated stock dowel holes and damaged flywheel mounting surface. Welded here for grinding to vary fit modification, will be equipped with four additional dowels. 11/32" dowels will usually save elongated holes.

the force is removed by the opening of the exhaust valve and the ending of the burning cycle, the crank tries to untwist itself. Such vibrations or harmonics can be tuned out or at least partially compensated for by a rubber and steel (or iron) vibration damper fastened to the crankshaft. It has a small-diameter and often fairly thick flywheel-like mass which is rubber-bonded to its mounting hub.

The lack of counterweighting on the stock VW crankshaft, plus the inherent torsional vibration tendencies of the four-cylinder design promotes crank flexing at high RPM. Admittedly, VW hotrodders (and even everyday U.S. drivers) are turning VW engines at RPM's Wolfsburg's engineering staff never intended—but that's no reason to ignore the problem. Racer Brown suggests that any torsional vibration damper (also called a harmonic balancer) will help the situation . . . even though none are specifically made for the VW.

Installing a damper requires fitting a seal at the No. 4 main to mate with the selected damper. The damper hub's inside diameter and keyway must be mated to the VW crank. If the crank has to be reduced in diameter, grind the shaft to new dimension—don't turn it in a lathe. Be sure to leave an adequate radius next to the main-bearing journal to avoid failures from a sharp corner. The damper itself must be dynamically balanced before it is installed on the crank.



A - 69 mm stroke crank with piston having compression height for that stroke.
B - 82 mm crank used with piston having 69 mm stroke compression height, note spacer required under base of cylinder so piston won't come out of cylinder.
C - 82 mm crank used with piston having compression height for 82 mm stroke.

STROKING

Longer-stroke cranks are used to increase the displacement of the VW engine. As with big-bore pistons, long-stroke cranks can be a truly trouble-free way to add performance. Power is added to the engine in almost direct proportion to the increase in displacement. Because the stroke is longer, the effective power range of the engine is increased so that more torque is developed at lower RPM than with the stock-stroke crankshaft (assuming that the same camshaft is used). Thus the car becomes more "drivable." And, because the longest-possible stroke that conveniently fits into the VW crankcase—82 mm (3.23 inches)—is still comparatively short, the upper-RPM limit of the engine is not reduced, at least not if the longer stroke is provided by a billet crank or a roller crank.

Increasing the stroke raises the c.r. (compression ratio) and may require reworking the cylinder heads to keep it at a reasonable figure. When the stroke is increased, the stock-stroke pistons come out of the cylinders at TDC (top dead center), requiring the use of spacers under the cylinders. And, the pistons are pulled deeper into the crankcase at BDC (bottom dead center) causing the underside of the pistons to hit the crankshaft and causing the rod to hit the opposite side of the case. The BDC interference condition is eliminated by machining a radius on the underside of the pistons, usually with a milling machine or a lathe fixture. If the interference is minor, it's even possible to clearance the underside of the pistons with a rotary file in some instances. All pistons must be the same weight, so piston rebalancing is always required after clearancing. A rotary file is also used on the case to provide rod clearance.

Spacers used at the bottoms of the cylinders should be as thick as one-half of the stroke increase. That is, if a 78 mm-stoke crank is installed in place of a 69 mm stock-stroke crank, the stroke difference is 9 mm and the spacers should be half the stroke increase or 4.5 mm (0.177 inch) thick. This assumes that you are using the same pistons and rods which were used with the stock crank which is being replaced. Otherwise, it's a whole new ball game and you'll have to figure out the spacer thickness so that you end up with the desired deck height between the flat top of the piston and the flat "quench" area of the cylinder head, *not less than 0.040-inch* as described in the engine-assembly chapter.

On any stroked crank, as with stock ones, any engine producing over 80 HP—or any engine to be drag raced—must be equipped with four additional dowels. All eight dowels should preferably be 3/4-inch length. Dowels are discussed earlier in this chapter.

Some mechanics have been known to compensate for excess compression height by taking a lathe or mill cut across the top of the piston instead of using spacers under the cylinders. Don't let anyone talk you into it! An article by Phil Vincent (famous motorcycle-engine designer) in Motor Cycle for July 22, 1965, pointed out that the piston crown should be thickened when the bore size is increased. He says that heat fed into the crown has farther to travel to the cylinder walls with the larger bore—and travels better through thicker sections. And, the large area of the piston crown means that there is more heat to transmit. Finally, the increased bore size has a larger total gas pressure acting on it and thus the increased diameter requires more thickness for this reason as well. If Vincent's remarks don't convince you, stop to consider that the head thickness of the piston was arrived at by the engineers to provide a margin of safety against failure when used in an engine producing stock horsepower. You are stroking the engine to make it put out more horsepower.

WELDED STROKER CRANKS

Welded stroker crankshafts for VW's cannot be recommended unless they have counterweights added to reduce the flexing tendency. As we put this second edition on the presses, only Gene Berg was offering such crankshafts, as described on page 78.

Non-counterweighted welded stroker shafts have been sold for years and the quality has varied from merely miserable to awful. Wear is typically very fast, especially with big-bore kits. The addition of more weight farther out on the crank "arm" merely aggravates the stock crank's tendency to pound out the case bearing saddles.

When you add up all of the costs involved, including $130 for the Porsche rods needed for strokes longer than 78 mm and then include marginal reliability—the welded, non-counterweighted stroker comes up *minus*. If you need a long stroke in your 1300/1500/1600—or even in a 1200, for that matter, the stock crank with added counterweights, or a roller crank (with a low-compression engine) is currently "the only way to go."

"STOCK" STROKER CRANK FOR 40 HP (VW ROD)

The 69 mm stock crank P/N 311 105 101F drops into the 40 HP 1200 VW like the factory intended everything to work out that way all along. It costs about $57. As already mentioned, the 40 HP engine has had its share of problems, but there are a lot of good 40 HP engines running around. If the cam bearings are not worn out—or if you have one of the replacement 40 HP engines which was supplied with the changeable insert cam bearings, you may be intrigued by the prospects of having up to 1602 cc. Some machinists who specialize in VW case work install the insert cam bearings and bore the case for oversize o.d. (outside diameter) main bearings.

First of all, remember that the 40

HP engine is narrower than the 1300 and later engines by about 3/4-inch. Thus, the sheet metal, connecting rods, pushrods, pushrod tubes, studs, intake manifold and exhaust headers are all shorter than the later stuff. So, to avoid the expense of changing these things for later parts, let's investigate what can be done to make your 40 horse come alive. The 1300/1500/1600 crank drops right into the case without any machining. The connecting rods are wider on the 40 HP so you'll have to turn approximately 0.020-inch from each side of the big end of each rod so that the big-end measures 0.900-inch wide. Don't get lazy and try to take 0.040 from one side because that won't work. Rod side clearance should be 0.008 to 0.0012 inch with the rod held against one side of the journal.

When this has been done you'll need cylinder spacers approximately 0.100-inch thick to go under each cylinder. Refer to the deck-height section of the engine-assembly chapter.

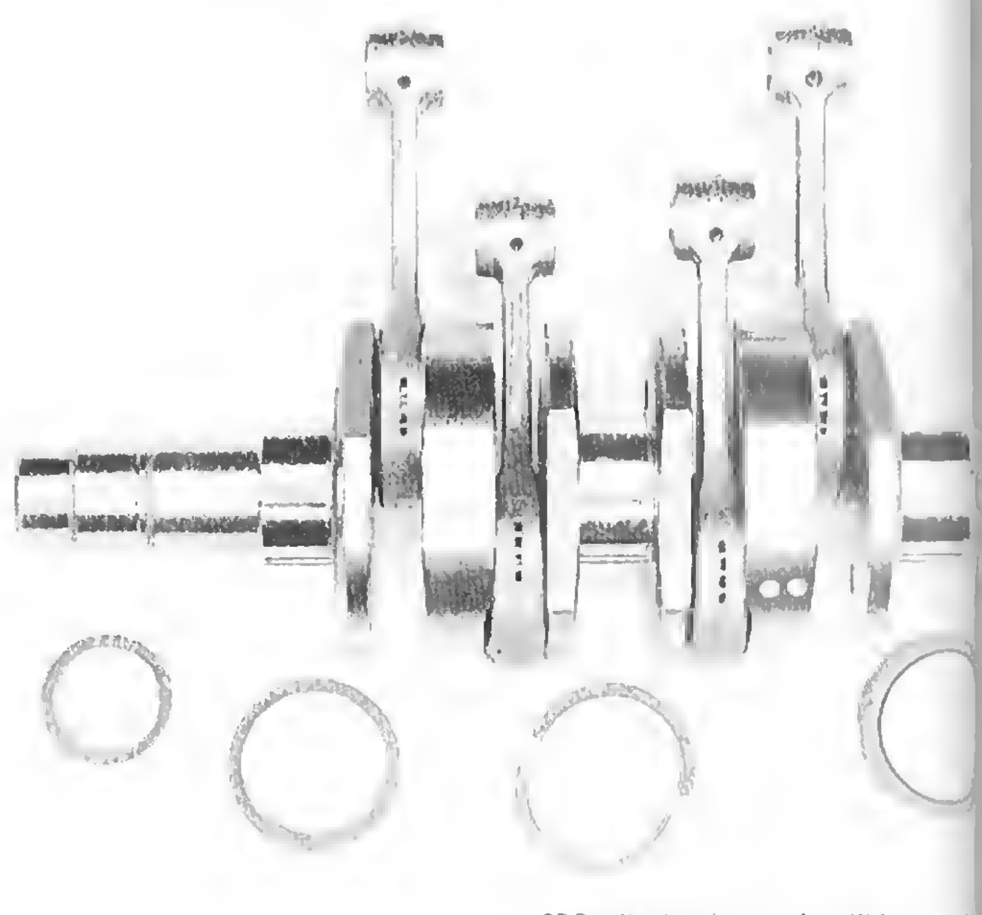
Reassemble the engine with the original 77 mm cylinders and pistons and you've got yourself a 1285 cc engine—the same size as the VW 1300. Or, buy the Kolbenschmidt 82 mm and 83 mm flat-topped piston/cylinder sets designed for the 40 HP (not a genuine VW part), install the spacers under each cylinder and your engine grows to 1457 cc or 1493 cc displacement, respectively, when installed with the 69 mm crank and the 0.100-inch spacers under the cylinders. There's even a 69 mm roller crank (made by SPG) for the 40 HP engine. It's the same as the other 69 mm roller cranks except for 40 HP length rods designed for use with the 20 mm piston pins. Although these cranks sell for under $150, you still have to install four more dowels and have the crank "anti-twisted" as described in the roller-crank section of this chapter. The 0.100-inch spacers are needed under each cylinder and the heads can be flycut or the rocker stands shimmed an equal amount to get the valve-train geometry nearly correct. Refer to the chapter on engine assembly for compression details before flycutting the heads.

You might think that this is as far as you can go unless you remember that "teaser" I threw in at the start of this discussion—about a 1602 cc 40-horse. Dig up a set of 36 HP connecting rods in good condition—have a set rebuilt—or buy new ones, P/N 111 105 401. A crankshaft specialty company can grind a 311 1969 crank's rod journals 5 mm (0.19685 in.) off-center to the 1.9685-inch diameter of the 36 HP rod journal. The journals are ground to a narrower width to give 0.015-inch side clearance on the 36 HP rods. The journals should be Tuftride hardened after grinding. You end up with a crank stroked to 74 mm. You'll have to use spacers approximately 1/4-inch thick under each cylinder. Refer to the cam and piston chapters for details on deck height and valve-train geometry. You'll have to cc your cylinder heads and check closely to keep the compression ratio at some reasonable figure.

There's even more displacement available through even larger bores and longer strokes for those who want to go all-out, but I'd have to recommend the 83 x 74 as a practical limit because the internal bracing of the 40 HP engine is just not as good as the later engines. And, when we start thinking about larger displacements, we are also talking about spending larger amounts of money—which will have a firmer foundation for performance with the sturdier 1300 or larger crankcase assemblies.

ROLLER CRANKS

The easiest way to increase the stroke of your VW engine is to install an SPG roller crank, complete with rods and bearings. Actually, these have roller bearings on only the connecting-rod journals. The main bearings are steel-backed bearing shells, generally known as "plain" bearings. The crankshaft assembly with rods weighs 36 pounds. SPG's own advertising sheets detail the features of these cranks as follows: "With the SPG roller-bearing crankshafts engines run cooler and power output is improved because there are less losses due to friction. The large counterbalanced webs of the SPG roller-bearing crankshaft ensure

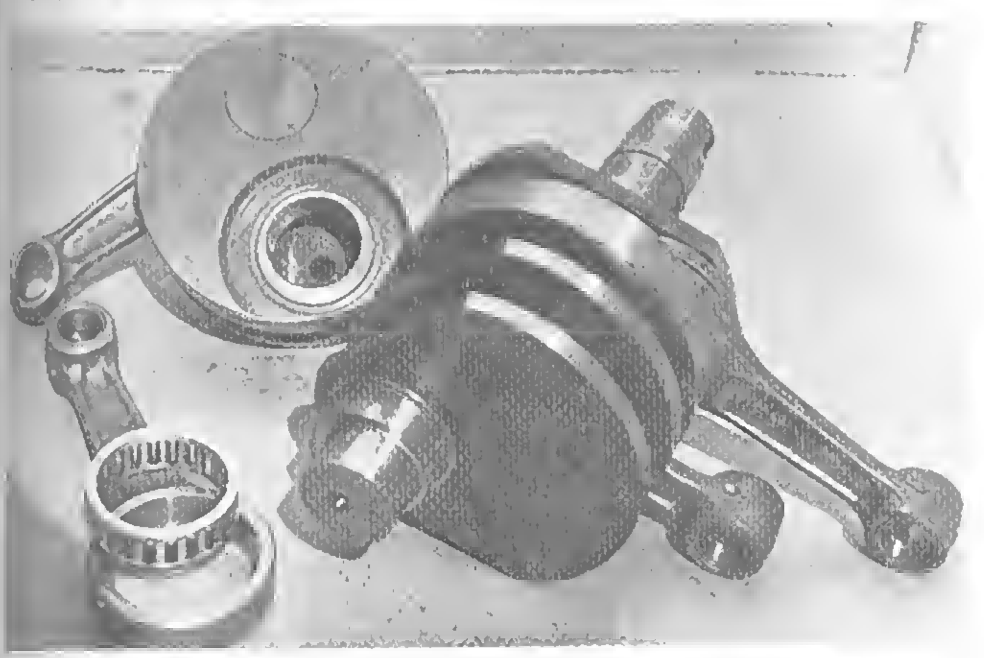


SPG roller-bearing cranks will let your VW rev like there's no tomorrow. Prices start at around $150 for stock strokes. Longer strokes cost more.

turbine-like smoothness and no crankcase wear. There is no chance of bottom-end failure due to over-revving. The connecting-rod big-end bearings are splash and oil-mist lubricated to ensure long life. Crankshaft oil holes are completely eliminated to provide journals which are wear resistant."

Ted Trevor of Crown Manufacturing points out that a certain amount of advertising "puffery" may be built into SPG's statements because *"truth is stranger than friction."* 'Way back in 1952, he measured the frictional differences between a roller bearing and a pressure-lubricated plain bearing. Seems that he was planning to build a roller-bearing crank for his flat-head Ford V-8, no less, and the services of the testing laboratory in one of the U.S.'s largest corporations were used to make the measurements. The tests showed that the pressure-lubed plain bearing had less friction than the roller bearing. Perhaps the ultimate crankshaft for the VW hotrodder may someday turn out to be a plain-bearing crankshaft built like the SPG, but with plain-bearing rods such as the 61-63 Oldsmobile aluminum V-8. Those rods are 0.300-inch longer than the VW rods, providing reduced rod angle and perhaps producing more HP.

You may never see a roller crank which has been taken apart because they are pressed together with such force that it takes two elephants and some fancy language to get one apart again.



SPG roller cranks are available in an almost infinite variety of strokes and models:

- 36 HP VW & 356 Porsche, 74 mm stroke
- 912 Porsche, 74 mm stroke
- 40 HP VW, 64 & 69 mm stroke (connecting rods 40 HP length and pin bushings fit 20 mm pins) with 4 dowel pins
- 1300/1500/1600 VW, 64 & 69 mm stroke with 4 dowel pins
- 1300/1500/1600 VW, 74, 78, & 82 mm stroke with 8 dowel pins

Installation Details - The only clearances that you'll have to worry about are in the crankcase and on the undersides of the pistons. Many of the big-bore pistons are already clearanced for the 82 mm roller.

One point of possible interference to be watched for is between the connecting rods and the cylinder bases. With the connecting rod at its maximum angle, it may contact the edge of the cylinder, requiring the addition of a small notch at the top and bottom of the installed cylinder base. Be sure to deburr any notches which you make at this point so that there will be no sharp edges to damage the pistons. The 74 mm cranks usually drop in with no case or cylinder modifications. About 1/32" trimming is required for the 78 mm cranks, and about 0.080-inch clearancing is required for the 82 mm cranks.

Many beginning mechanics go "wild" with their files, chisels and grinders—taking out far more metal than is necessary and consequently weakening the crankcase with all of their extra hard work. Grind or file only those areas where there is interference and do that a little at a time. If there is as much as 0.040-inch clearance that is plenty. Don't overdo it!

Piston Details For Roller Cranks - In addition to clearance under the piston pin boss (to clear the full-circle counterweights), the distance between the pin bosses inside of the piston must be 1.240 to 1.280 inch (31.5 to 32.5 mm). This provides inch clearance at each side of the small end of the connecting rod. Any larger opening between the pin bosses will not provide adequate guiding for the top end of the rod and "cocking" of the connecting rod can result, destroying the rollers and the crankshaft.

Use The Correct Bearings With Your Roller Crank - The main bearings supplied with the roller crank are specially machined to supply an oil spray or mist to the rod bearings. If you replace the main bearings, use bearings with equivalent notches/grooves or you'll lose the engine almost immediately after firing it up. SPG calls this spray system "Micro" jet impact oil atomizer. They claim that the elimination of all crankshaft oil holes keeps the steel parts bright and free from abrasive particles, even after thousands of miles of hard and fast driving. Stock main bearings can be modified exactly like the SPG's.

Balancing Roller Cranks - The roller cranks are balanced to one cm/gram as they come from the factory. Don't buy a rebalance job on the crank assembly. Anyone who tries to sell you one is "putting you on." Balancing should only be required on the crank pulley, piston/pin/ring assemblies, and the flywheel/pressure-plate assembly. The roller crank cannot be easily disassembled to allow balancing of the rods for total weight, end-to-end weight, etc.

Which Stroke To Buy? If you are going to install a roller crank, buy the longest stroke available so that you end up with the maximum possible displacement . . . unless the rules of a particular racing association demand a stock stroke. The price will be the same for any stroke

longer than 69 mm (stock stroke) anyway, and all of the longer-stroke cranks have eight dowels. When the price is the same always get the largest because cubic inches are the cheapest—and the least troublesome horsepower—that you can buy.

Dowels For The Roller Crank - All roller cranks with strokes longer than 69 mm have eight 8 mm dowels. These have proved to be adequate for very high output VW engines, so there's no real reason to change them. These dowels are in the same pattern as that provided by Crown's lightweight flywheel and by Tayco's flywheel/crank drilling fixture. So, you can either get a Crown flywheel or buy an EMPI, Crown or Tayco fixture to drill your own flywheel—or have the firm that sells the crank drill your flywheel to match the dowels in the crank.

If you buy a 64 or a 69 mm roller crank—for any VW engine, regardless of its use—get the firm that sells it to you to equip the crank with another four dowels.

8 dowels are standard on SPG cranks with strokes longer than 69 mm. Those with 4 dowels should have the extra ones added to ensure a good connection with the flywheel. Dowels supplied in SPG cranks are short. Longer ones (3/4-inch) can be installed if you can ream out the holes with a drill. It's tough work because the surface is so hard.

And, have them drill your flywheel to match. Because the roller crank is harder than the hinges of Hell, you'll need carbide tools and a specially ground carbide reamer to install the dowels. Not much interference fit is wanted, either, because too much will split the No. 1 journal as if it were glass. About 0.0005-inch interference is plenty. Here again, unless you are going to do these cranks all day long, leave that chore to an expert . . . or forget it! Ted Trevor says, "Heat-treated 8 mm dowels in a heat-treated crank such as the SPG with a heat-treated flywheel make a considerably stronger connection than a soft flywheel and crank with 11/32" dowels. As for the earlier analogy of a fence post—try wiggling that post when it's in well-set concrete instead of dirt."

Flywheel Weight For Roller Cranks - A lighter-than-stock flywheel is recommended by SPG in their installation instructions. They suggest that the flywheel be lightened to 10.5 pounds or lighter and then dynamically balanced with the clutch pressure plate.

Important Modification - If you buy and install one of these cranks it is important that you promise yourself never, ever to drag race from a standing start. Why take such a pledge? Because the shock of a high-winding engine suddenly engaged to a brutal clutch which may be connected to sticky tires twists the roller-crank assembly out of alignment. A twisted roller-crank assembly turns your engine into junk right now!

But didn't Porsche once use roller cranks—and in their racing models? Sure, but their roller cranks were of the patented, expensive-to-build Hirth construction with splined connections at every "twistable" joint. As of 1970, all roller cranks for VW's were pressed together. There are no keyways or splines to ensure that alignment is held when the clutch is treated brutally—as in the case in standing-start drag racing. The roller crank can be used for non-drag-raced VW's of up to 120 HP—if you always roll away from the stop lights gently before climbing onto the throttle.

As hotrodders saw the virtues of the SPG roller crank, the inventiveness of the Southern California VW racers came into play to eliminate the "twisted joint." Competition Engineering's Ray Litz and Gene Berg of Gene Berg Enterprises now heliarc weld about one-half of the circumference of the rod-journal end to the counterweight. This costs approximately $25.

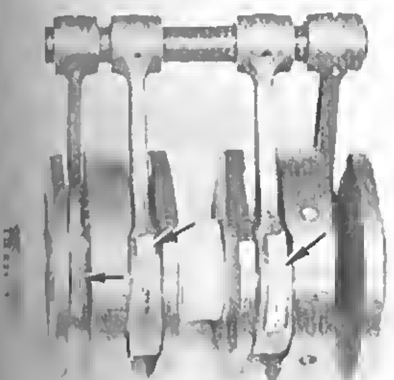
At the end of Summer, 1970, EMPI began importing an 82 mm stroke EMPI SPG roller crank specially made with pinned journals and longer rods for improved rod angularity. This could mean that all SPG cranks might eventually come to the U.S. set up correctly for our kind of racing.

SPG roller crank which was jerked out of true in severe racing use proves beyond doubt that welded or pinned journals are essential. Dashed-line reference shows how far this one twisted.

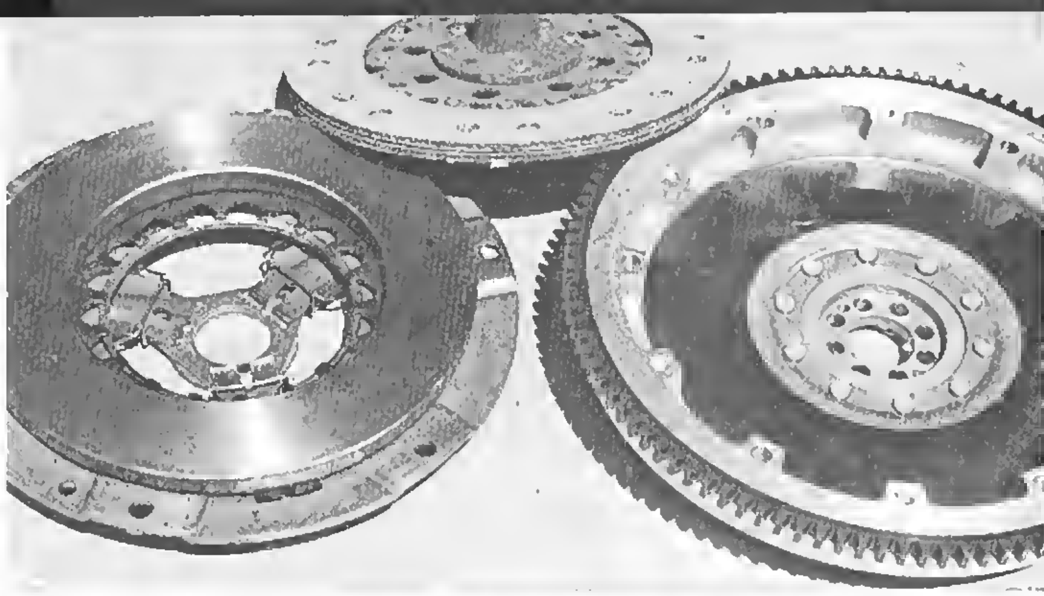
Compression Ratio Limitation - Do not run high compression ratios with the roller-bearing cranks as the aluminum cages for the rollers will deform when the engine has any amount of detonation, thereby converting your expensive crank into instant junk. Gasoline quality as of 1972 is trending downward because modern-day emission-controlled engines do not have high compression and do not require high-octane fuels. Anything above 8 or 8.5:1 is not recommended (by the author) for use with the SPG crank, as the life will be dramatically shortened by higher compression ratios.

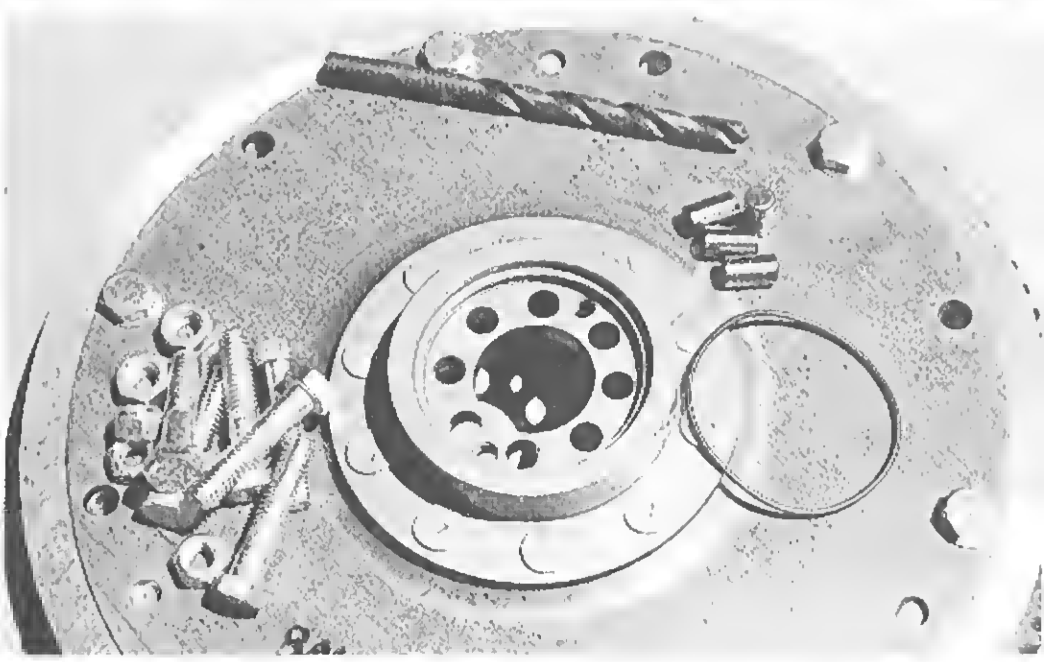
Rebuilding Roller Cranks - As of 1970, no U.S. firms were equipped with the necessary fixtures to work on the roller crankshafts. If problems occur, the usual remedy is to buy a new crankshaft, complete with rods and bearings. Fortunately, as long as the cranks are anti-twisted and RPM's limited to 7,000 per the SPG factory's recommendation—troubles are few and far between. The cranks have an enviable record of long life.

Availability - Because the cranks are imported from Germany, when the U.S. supply runs out there is sometimes a delay of several months in filling orders. Allow ample time to get the crank before scheduling assembly of your engine. Keep that fact in mind and be prepared to make telephone calls around the country until you find what you are looking for (or give up!) —especially if you are in a hurry. The best plan is to wait patiently until you have all of the parts at hand before planning to make a given race with a new engine.



If you don't read German you may wonder what's printed on the cellophane tapes (arrows). Each one says, "Remove before running." Tapes keep dust out of the rollers on the rod journals.



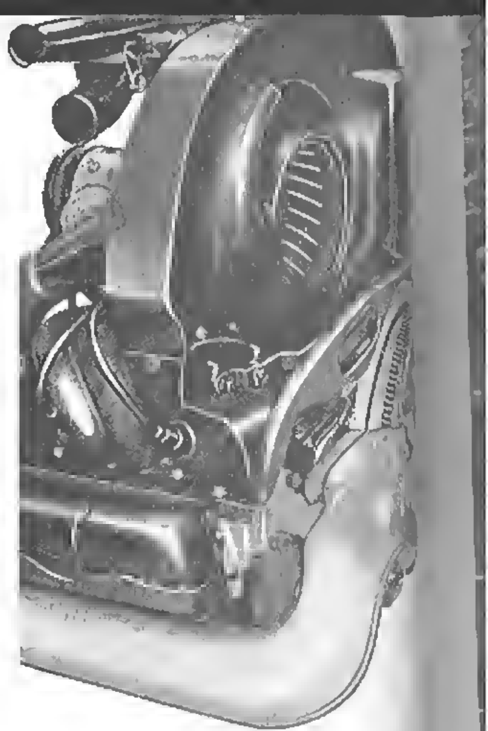


Crown's 200 mm diaphragm clutch is the hot setup for VW racers—whether VW or Corvair powered. It's the only clutch that will hold a high-revving, high-HP engine. Because two pressures are offered, consider your needs carefully before buying. Use a heavier one for all-out racing, but stick with the lighter one for street and average off-road use. Even the light one will wear out your leg when you push on the pedal, so buy one of their hydraulic actuating systems when you get the clutch. You'll need one eventually—or a new leg. Clutches fit in stock flywheels or Crown's O-ring-type super-lightweight (6.5-lb.) flywheel with hardened center. It comes with a drill and dowels so you can add 4 dowels to make the connection secure. Note tapped holes for use in pulling flywheel.

Stock flywheels on left—chopped flywheels on right. Note that weight is taken off at outer rim, leaving only sufficient material to support the starter ring gear.

Lubrication, cooling & breathing

VW's are cooled by oil as well as air



Photos courtesy Volkswagen of America, In

Everything you do to increase VW power simultaneously increases the production of heat. Maintaining engine temperatures at usable levels requires increasing cooling abilities as you accomplish other modifications. Because oil is an essential element for eliminating heat from the VW engine, lubrication is discussed in this chapter as inseparable from air and oil cooling.

You cannot increase the cooling-fin surface area of the VW cylinders or heads. VW's careful engineering of these items provides maximum heat removal from the available cooling air, consistent with the limitations of modern volume-production techniques.

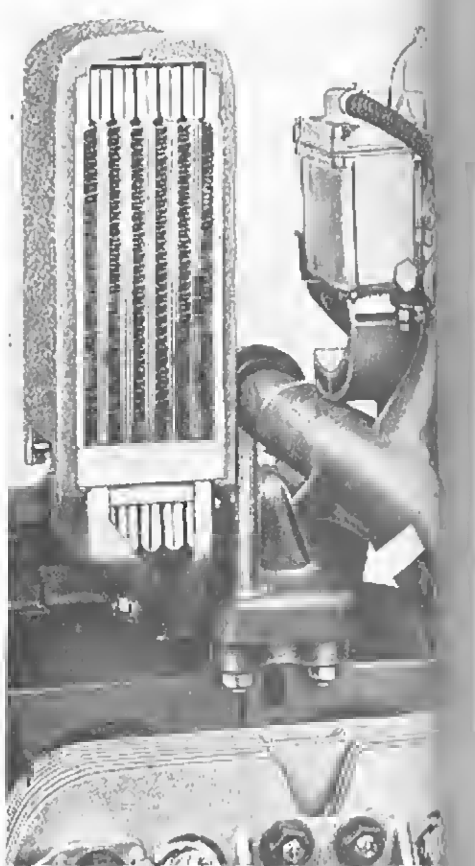
You can greatly improve cooling by changing to a Porsche oil cooler or to an external oil cooler, adding an extra oil sump and by improving the heat-radiating characteristics of the engine's cast-iron, aluminum and magnesium surfaces, both finned and otherwise. Some improvement is possible through exchanging the sheet-metal valve covers for finned-aluminum ones. Added cooling is also available through better use of the oil's heat-removal characteristics via increased flow made possible through cooler and oil-pump modifications. Adequate crankcase breathing also helps to keep engine temperatures at reasonable levels. These modifications are fully described in this chapter.

STOCK COOLING SYSTEM

Although it might appear that the VW is the same yesterday, today, and tomorrow—nothing could be farther from the truth as regards its cooling and lubrication systems. Detailed changes which have been made deserve your careful consideration and understanding. Some of these changes include the way that oil is routed to the cooler, increased size of the oil passages, oil-pick-up tube size and oil-pump capacity. There are also differences in the cooling fans and in the speeds at which they are driven.

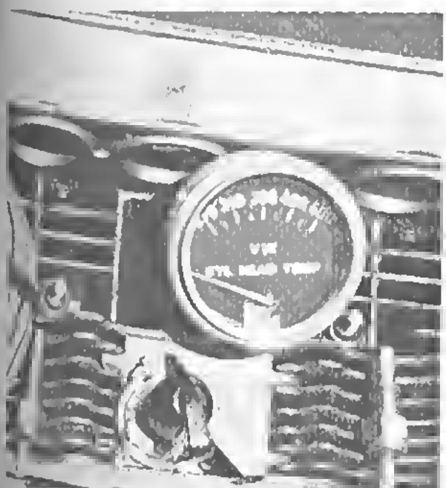
The VW uses forced-air cooling. Sheet-metal shrouding directs air over the cylinder heads, cylinders, and oil cooler. Thermostatic cooling control is provided on 1966 1200A and later engines by bellows-controlled air-control flaps at each side of the engine. These flaps open when temperature of the air under the cylinders reaches 205°F. 1100 and early 1200 models differ in that cooling air is controlled by a thermostatically controlled air throttle ring on the blower-fan inlet. This shuts off all of the air coming into a cold engine and at the same time effectively prevented any air from circulating in the car. Thus, the early models were real "iceboxes" in wintertime. The cooling flaps or inlet ring cause the engine to operate as if it were in an 80°F ambient temperature. An engine blower fan is mounted on one end of the generator shaft. It is belt-driven at approximately 1.8-times engine speed depending on the diameter of the crankshaft pulley. A fan on the end of the crankshaft is used in fast- and squareback models. These fans obviously run at engine speed.

You don't want any cooling air to escape from the engine without doing its share of the cooling job, so be sure to plug any openings in the sheet-metal cowling, including making sure that the spark-plug seals are correctly installed and that the heater openings, if not used and connected to the heater hoses, are securely closed off. Remember that the *engine compartment seals are essential.* They keep hot air from the exhaust and cylinders out of the engine compartment so that the cooling fan gulps only cool air for maximum cooling. Leave



Arrows indicate doghouse on back of 71 engine. This puts cooler away from blast which cools cylinders 3 and 4. Installation of this fan housing and cooler relocation (Type III cooler used) recommended for any pre-71 VW on which cooler is not being taken out of the fan housing.

Entire shroud with generator attached lifts off of the engine to allow installing new manifold. Keep the thermostat-controlled air flaps for best engine life and best HP when the engine is cold. Note that heater outlet has been plugged with a rubber ball so that no cooling air will be lost. Broken plug seal should be replaced for same reason.



off any of the seals (including the plug seals and/or the heater outlets) and the engine will run much hotter—thereby reducing its performance potential because recirculating hot air gets progressively hotter and hotter and hotter.

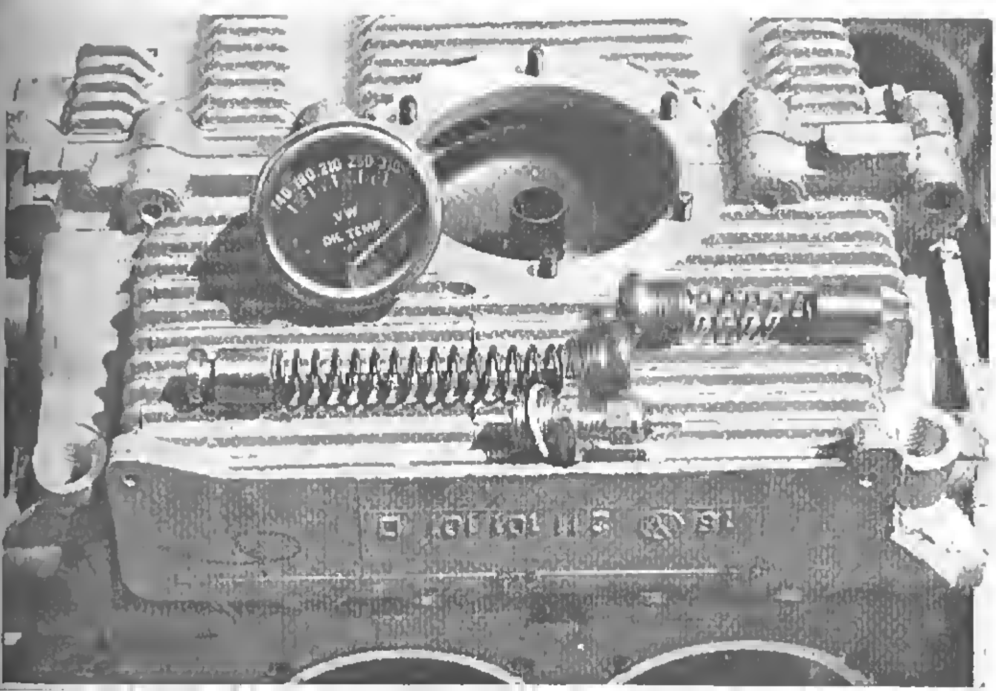
HOW HOT IS THE ENGINE GETTING?

The factory keeps you in the dark on this question when you are driving the car. Nothing warns you of an overheat condition. If you plan on serious competition with a VW engine, a cylinder-head-temperature indication and a measurement of oil temperature are very useful.

We do not know of any published figures for VW cylinder-head temperatures, but some Corvair figures may be of interest. A Chevy dealer bulletin advised cylinder-head temperatures as: 200° to 300°F at idle; 350° to 475° at 30 to 60 MPH cruise; and 460° to 575° from 3,000 to 5,000 RPM at full-throttle. These figures were for the turbosupercharged Spyder models.

According to Mackerle, oil temperatures should be maintained above 176°F to keep down friction loss and dilution by gasoline, and should not exceed 230°F for continuous operation. Up to 230° may be considered permissible for short bursts.
Crown's Ted Trevor says, "280°F may be deplorable, but it's not an uncommon condition in a high-HP VW or Corvair engine." Jeff Quick of ACE claims that up to 275°F can be considered acceptable with a good 40 to 50-weight oil.

Cylinder-Head Temperature Gages - Cylinder-head temperature can be measured with Radatron Kits 3711, 3721, and 3731.



Radatron's VW instruments advise you of vital temperatures and pressure in your valuable engine. Above left photo shows two cylinder-head-temperature senders installed in head fins and two senders for the other head, plus gage, selector switch and wire. Oil-pressure gage (above) sender installs in case in place of stock idiot-light switch or can be placed in tee fitting to retain the switch. Lower photo shows oil-temperature gage with sender which mounts at rear oil-pressure-relief valve in place of stock nut under spring. Note that 70-71 cases as shown here have a solid (not grooved) relief valve near the flywheel and a grooved one at the rear. It is essential to use the correct springs and relief valves in the late cases. Note 7/8-inch-diameter oil pickup used in these cases.

Each kit has a 500°F VW cylinder-head-temperature gage and a sender which installs in the cylinder heads between the fins. The 3711 kit measures only one cylinder, so install its sender at the No. 3 cylinder—because it usually runs about 30° hotter. The other kits (3721 and 3731) have four senders, one for each cylinder—and a four-position rotary switch. You can select the cylinder that you want to watch for temperature. You'd leave the switch set to measure Nos. 3 or 4. These cylinders run hotter than Nos. 1 or 2 because the stock oil cooler disturbs the flow of air over these cylinders. That's why you may want to consider using an external cooler as discussed later in this chapter.

Cylinder-Head Overheat Warning - Whether or not you install a cylinder-head-temperature gage, you may like the idea of having an overheat warning indicator. Inexpensive Corvair overheat switches ($2 each) can be screwed into the fins or into a boss on the head. Buy either P/N 1993599 or P/N 1993547. Either of these provides a switch closure to ground when cylinder-head temperature reaches approximately 575°F. The first of these switches, used on Spyders and 140 HP engines, has 3/8-24 threads and the latter (from 60-64 engines with air conditioning) has 3/8-16 threads. You'll only need one of these switches. Install it at No. 3 cylinder head. Wire it to your VW oil-pressure sender with a single wire between the two senders. Each one lights the idiot light by completing the circuit to ground.

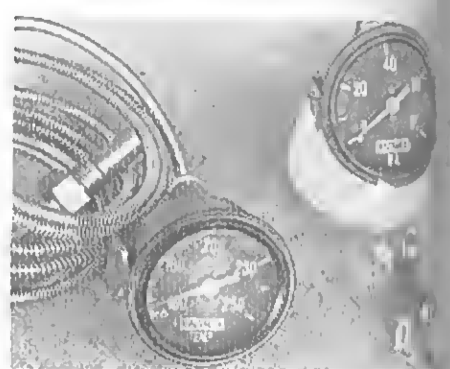
Oil-Temperature Gages - Oil temperature can be measured with an electrical sending unit at the engine connected with wire to a temperature gage. There are also mechanical sending units which are connected by a tube to the temperature gage. However, these require a fairly long tube between the gage and the engine—unless you mount one on the firewall ahead of the engine.

Although most special oil sumps can be drilled and tapped to add a sender, the bottom of the oil sump gives a false too-cool reading which should not be relied on for accuracy. The best place to measure oil temperature in the VW—as the oil leaves the cooler—is not easy to get to because the oil-cooler outlet delivers the cooled oil directly to the main oil passages.

EMPI instrument package includes wiring diagram and a complete wiring harness. The complete package installs in one hour in a VW sedan. Nippon Seiki, suppliers of instruments used in Honda cars and bikes, makes the setup.

Warning - It is especially important that you be careful when installing an oil-temperature sending unit—either mechanical or electrical—so that the temperature sensor does not extend into an oil line or passage so as to block the oil flow.

Radatron gage kits 3811, 3813 and 3834 are designed specifically to advise you of the oil temperature in your VW. The sender installs in the oil-pressure-relief valve so that it does not block the oil flow or relief operation.



Racimex instruments for oil pressure and oil temperature are widely available. Oil pressure gage retains idiot-light sender, but uses tiny hose which gives too much lag in the oil-pressure reading. Hose should be replaced with 3/16-inch i.d. stuff for good gage response. Mechanical sender on the oil temperature gage must be long enough to reach to your dash or you'll have to invent some unusual location for it.

OIL-PRESSURE MEASUREMENT

Oil-Pressure Idiot-Light - Oil pressure is neither measured nor indicated. *The oil-pressure indication is far too slow!* When your VW engine's oil-pressure drops to 2 to 6 psi, the oil-pressure warning light tells you that you have insufficient oil-pressure. This warning system is inadequate for any high-performance VW. By the time the light comes on, damage has probably already occurred. For this reason an oil-pressure gage should be considered even more important than the cylinder-head and oil-temperature gages or warnings which are detailed herein. However, you should keep the idiot-light circuit and sender intact and use it for a catastrophic warning by wiring it to a large clearance light on the dash or to a horn relay so that you'll either be partially blinded by the big light—or awakened by the horn blowing in the event of oil-pressure loss.

Oil-Pressure Gage - As with the cylinder-head temperature gages, there are two kinds of oil-pressure gages: mechanical and electrical. The mechanical type requires connecting a tube between the engine's oil system and a gage which can be mounted wherever you choose. This is the most direct method and least expensive. The electrical type uses a sender at the engine connected by a wire to a gage which is connected to the car's electrical system. The senders are not always accurate and I have spent many hours trying to

track down oil-pressure loss when all I had was a bad sender, even though it was brand new. This is not said to knock the electrical type—just to make you aware of another possible area to consider when troubleshooting. Installation of this type gage is comparatively easy, as it is only necessary to mount the stock oil-pressure switch with the pressure sender or mechanical connection (tube) onto a tee. Actually, it is safer and more desirable to measure the pressure at a point more remote from the pump output, such as at the main oil gallery near the flywheel end of the engine. Unfortunately, it is difficult to tap into the oil supply at No. 1 main bearing, but it can be done.

Jim Herlinger says, "Gage lag is severe when you have a long tube from the rear engine to a front gage. In Vees I've seen 30 psi on the gage with the idiot light on, then the light goes out about the time the gage falls to 5 psi."

Several of the gage manufacturers offer both electrical and mechanical oil-pressure gages. Some are calibrated in Fahrenheit and others in Centigrade. One of VDO's oil-pressure gages is operated electrically from a "dual-purpose" sender which also incorporates the switch for the idiot light.

WHY SPECIAL FAN PULLEYS?

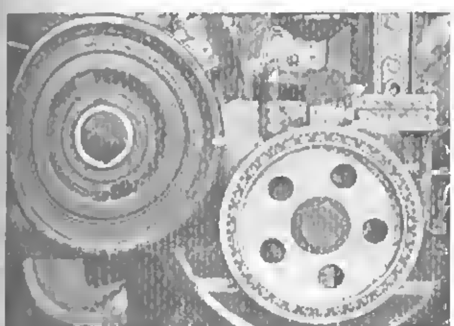
Adequate cooling for the worst load and ambient-temperature conditions, including full-throttle operation in summer temperatures, is provided by the stock system. Turning at 1.8 times engine speed, the fan supplies air at 1260 cubic feet per minute at 4,000 RPM (engine speed). This is sufficient for continuous full-throttle operation and is absolutely necessary for hard driving in hot climates or for road racing. "Flat-fan" engine blowers give the same CFM output.

Horsepower is needed to spin the VW fan and the same is true for a water-cooled engine's fan and water pump. But, the water-cooled job has the additional task of pushing air through the radiator. This means non-streamlined air flow and increased wind resistance. Thus, when all factors are considered, the air-cooled engine probably requires less HP for cooling, especially at part-throttle cruising. Only 3.5 to 5.5 HP is required at 60 MPH in high gear (3000 RPM). Fan-power requirement increases as the *cube* of speed and is dramatically detailed for stock and special-ratio pulleys by the fact that a small pulley saves 4.2 HP at 5000 RPM and 6.1 HP at 6000 RPM. There is no easy way to reduce the horsepower required to turn the fan on the "flat-fan" engines because these fans are connected directly to the crankshaft.

For street or highway operation where ambient temperatures are not extreme, reducing fan speed adds horsepower you can feel! When a special pulley is installed you must stay alert to the possibility of overheating because less cooling is available at any given speed. And, you may want to install oil-temperature and cylinder-head-temperature gages as described elsewhere in this chapter.

To install a special crankshaft pulley requires using a shorter belt. One of the slickest, most carefully thought out VW accessories is the Santana fan pulley. The pulley is cast from 356T6 aluminum. It is only 5-3/4-inch diameter, (same diameter as Porsche) compared to the 6.7 or 7-inch diameter of the stock VW pulley. There's another very good reason to replace the stock pulley if you are building an engine to turn at high RPM's. The stock pulley literally comes apart at high RPM because it is being used far beyond the operational limits for which it was designed. The Santana pulley is well-balanced as it comes from the maker. It is also available in stock size for those who need all of the cooling power of the VW fan.

The hot tip for Vees is Silicone lubricant on the fan belt so that the loose belt slips over the pulley without driving the fan at full speed. The problem, however, is one of gaining HP versus frying the engine should the belt slip too much. Incidentally, Vee builders also make sure that the stock pulley that they use is the welded one—not the riveted one.



"Free" horsepower (well, almost) comes from use of smaller-than-stock Santana aluminum pulley. Degreed type simplifies ignition timing and cam checking. Santana also offers stock-size pulley with degree plate. Stock pulley is shown at left for comparison.

THERMOSTATICALLY CONTROLLED COOLING

One of the bits of misinformation which prompted me to write this book was the widely believed fiction that the VW's thermostatically controlled cooling system should be disabled. Don't let any would-be automotive expert talk you out of keeping the thermostatically controlled cooling-air feature of the VW. The throttle ring or flap controls are absolutely needed and only the stupid person takes them off because he refuses to think. If a part can be safely left out of an engine or off of a car—you can be sure that the manufacturer won't put it on in the first place because the automotive engineers almost always go by a slogan of the famous GM engineer, Boss Kettering, " Parts left out cost nothing and cause no service problems." If there was any other way for VW's engineers to insure that the engine got fast warm-ups to avoid sludge and acid formation (and therefore fast engine wear)—other than controlling the cooling air—you can be 100% sure that they would do it in a minute.

Part of this problem probably stems from the fact that many mechanics blocked the inlet rings open on the older models to get more heat quicker in cold climates. There's no excuse for this with the flap controls because the car heat is not affected. One "performance manual" and several "performance articles" have recommended that the air-control flaps should be propped open permanently or the air-throttle ring eliminated on the 1100 and early 1200 models. This same writer further stated that "no damage could result and this would *reduce* the amount of horsepower required by the blower fan." Thus, many VW owners have gained two misconceptions. Let us examine these "recommendations" in detail. First, blocking the air-control flaps or inlet ring open *increases* fan-horsepower requirements. Moving the maximum volume of air when the air control flaps are fully open for maximum cooling

takes more power to push the air through the cylinders and the oil cooler. Fan HP requirements are reduced by *closing* the air control flaps *and* the heater and carb-heat ducts.

Secondly, blocking the air control flaps open increases engine wear by lengthening the warm-up time. Open air-control flaps eliminate one of VW's more desirable features—quick warm-ups. A quickly warmed-up engine suffers less wear, especially when it is allowed to reach and maintain its normal operating temperature for a period of time prior to shutting it off. Short hops during which an engine never warms up increase oil dilution by gasoline, build up varnish and sludge accumulations, and greatly increase cylinder wear. The high wear rate is caused by combustion products which condense on the cylinder walls to cause etching and rapid wear.

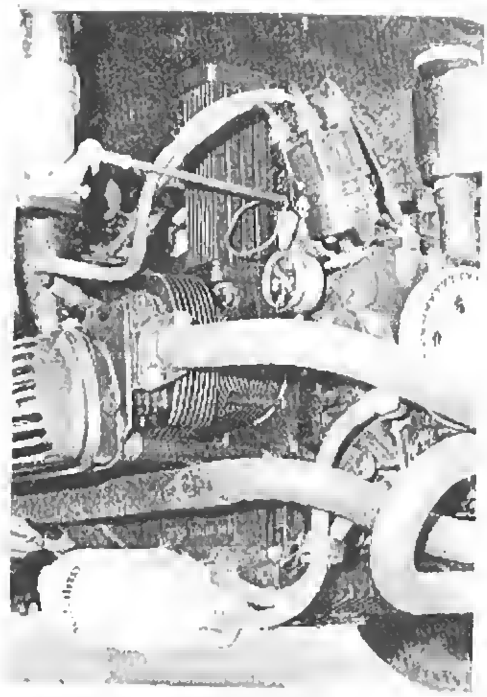
Cold cylinders also mean thick oil which increases the friction that pistons must overcome. The hotter the cylinder walls, the less friction loss, especially with high-viscosity oils.

You can check this oft-proved and well-documented series of facts in any internal-combustion-engine textbook.

For drag racing you can block the air-control flaps closed for the race, then open them immediately afterward. If a working generator is not required by the rules, remove the belt for the race and simplify the entire procedure . . . and get even more horsepower. Don't continue driving without the fan . . . you'll need a push or tow from the end of the quarter mile back to the pits.

If you leave the belt off, you should "motor" the generator, that is, use the generator as a motor to turn the fan. This can be done easily by making a jumper wire with a clip on each end. Just jumper between the red and blue wires on the voltage regulator. A switch could be installed on your dash to do the same jumpering. This helps to avoid distortion of the cylinders and heads by keeping a flow of air over them. Otherwise, the shrouds hold the hot air around the engine and cylinders and heads can warp because they do not cool evenly.

The avid drag racer will usually add two extra shims to the generator pulley so that the fan belt can be flopped off just before coming to the starting line—and flipped back on at the other end before driving back down the return lane.



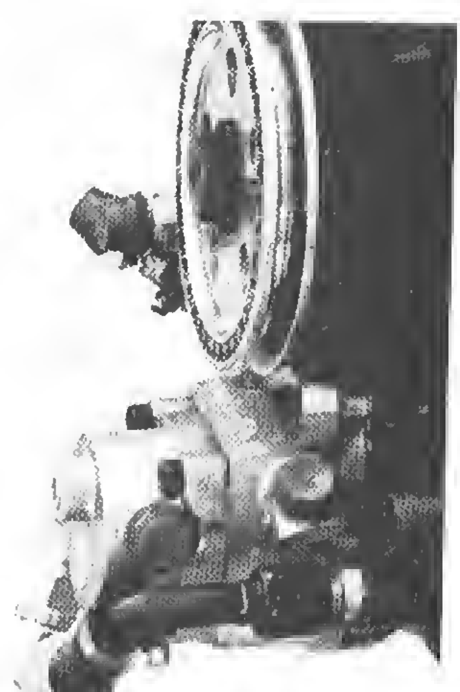
Drag-race dune buggy shows a lot of no-no's. Oil filter is mounted where it can be damaged and oil lines terminate with banjo fittings which are highly restrictive. Plug wires taped together may cross-fire at high RPM—and oil-pressure gage is of NO use to driver.

OIL FILTERS

When the engine is being modified for competition, use a large full-flow oil filter mounted near the engine. It will give added oil capacity along with filtering. Perhaps the easiest full-flow filters to adapt are those made by Ford. Oil-filter adapter Part No. C3AZ-6881A used on the 427 engines has threaded holes for the oil-pressure sender and it is easily adapted to a Fram HPK6 with 1/2-pipe-threaded openings. Or, use a one-piece filter base with tapped holes. These are made by ACE, Fram and Transdapt.

Hoses to and from the oil filter must have a minimum inside diameter of 1/2-inch. This inside diameter is essential to avoid oil starvation when the oil is cold. Avoid interference with the fan belt and crank pulley. Arrange the hoses so that they do not have to be removed to install a new fan belt. Keep the hoses short.

It is very important to use hoses designed for oil service. They must be specified for long life at temperatures to 350°F or so. Aero-Quip braided-steel-covered hose is possibly the best you can purchase for use with an external full-flow filter or for plumbing to a remote oil cooler. This hose, and non-sheathed hose for oil service, will be available at firms specializing in aircraft or truck components.



ACE dry-sump oiling system sells for \$125, is Super Vee legal part. VW pressure pump is fed oil from external reservoir, pumping it into the usual stock oil passages. Scavenge pump at rear of assembly sucks oil out of engine through stock pickup, then pumps it back to reservoir. Scavenge pump must be twice as large as pressure side to handle foamy oil from sump.

Royal Brass in San Jose, California has always had the pieces—and good advice—I've needed for such installations.

FULL-FLOW OIL FILTER

Because the stock VW comes with no oil filter, installing a full-flow filter may seem needlessly costly. Simple machine work is also required, so many owners are tempted to shrug their shoulders and say that they will get to this kind of problem later in the day—year—or some other time. Do it now if you are planning to race—unless your pocketbook is bottomless and you enjoy buying new parts and assembling an engine every week-end.

So, what's so great about a full-flow filter and why should you have one? *Full-flow oil filters reduce engine wear up to 66%!* Ford Motor Company, which has used full-flow filters in most of their engines for many years, published some startling comparisons of the wear reductions which can be expected when a full-flow filter is used instead of a by-pass-type filter. In an SAE paper published in the 1950's, Ford showed reductions of 50% in crankshaft wear, 66% in wrist-pin wear, 19% in cylinder-wall wear and 52% in ring wear.

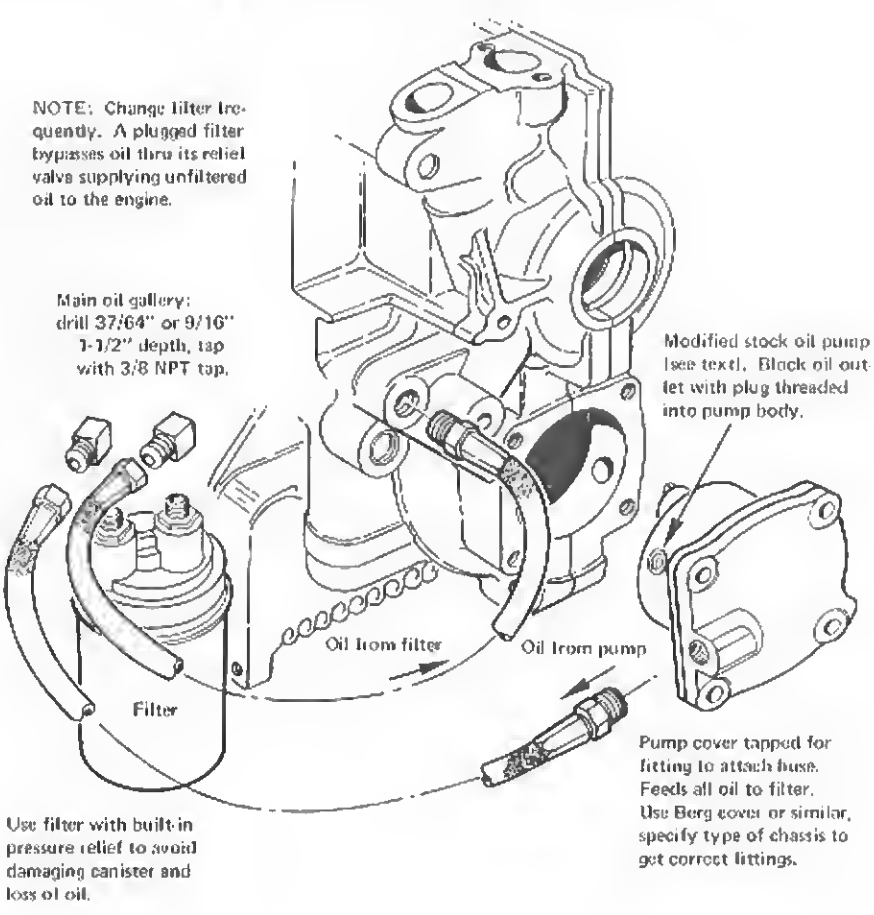
The VW engine, like many other engines which have been converted for high performance, suffers from a bad case of "quick death" when run at high horsepower output without a full-flow oil filter. Much of the engine wear occurs from dirt or particles of metal which are seldom completely removed from the engine when it is first built or overhauled. Some of the engine wear comes from wear products—bearing particles, pieces off of the camshaft or lifters, minute bits of carbon which somehow manage to get past the rings, and tiny chunks of aluminum which are worn off of the head or valve-spring retainers by the valve-springs (especially when the valve springs are seated directly against the aluminum surface of the head—instead of against shims as is correct procedure). When these are recirculated through the engine with the oil, additional wear is caused, adding to the quantity of unwanted junk in the oil on a continually increasing basis so that the oil becomes a carrier of wear-producing material instead of a flow of life-sustaining lubricant.

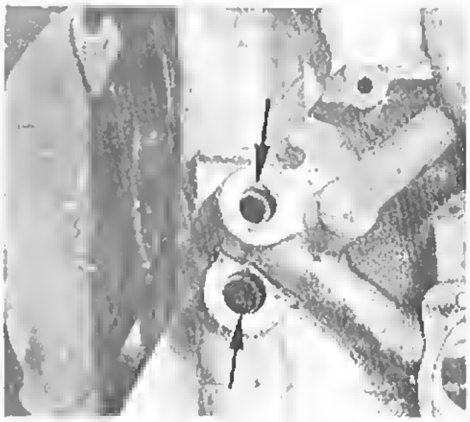
Installing The Full-Flow Filter - The machine work mentioned in the beginning of this discussion is quite simple. The end of the oil gallery in the left crankcase half is opened by drilling through the aluminum plug and twisting this out with an EZY-OUT broken-screw remover, or you can thread a long bolt (with a sliding knocker) into the plug and knock it out. Drill the end of the gallery 1-1/2 in. deep with a 9/16-inch drill. Tap the gallery with a 3/8 NPT (pipe thread) tap, using the fitting which will be threaded into the gallery as a guide. Keep taking out the tap and screwing in the fitting after you have made a thread or two.

Don't get the tapered pipe thread so deep that the fitting bottoms against the crankcase surface. The fitting must screw in solidly without bottoming its hex-nut surface against the crankcase. The oil from the full-flow filter will enter the engine at this tapped end of the main oil gallery.

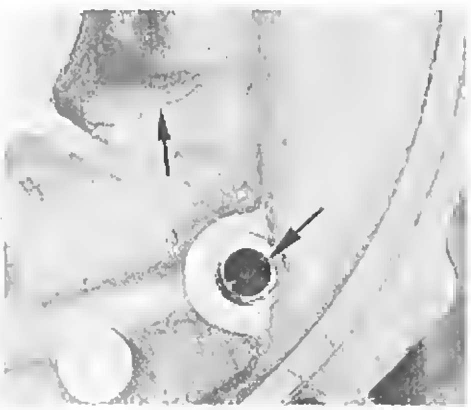
Complete details for modifying the VW oil pump are in the oil pump section of this chapter.

SCHEMATIC FOR FULL-FLOW FILTER AND/OR COOLER

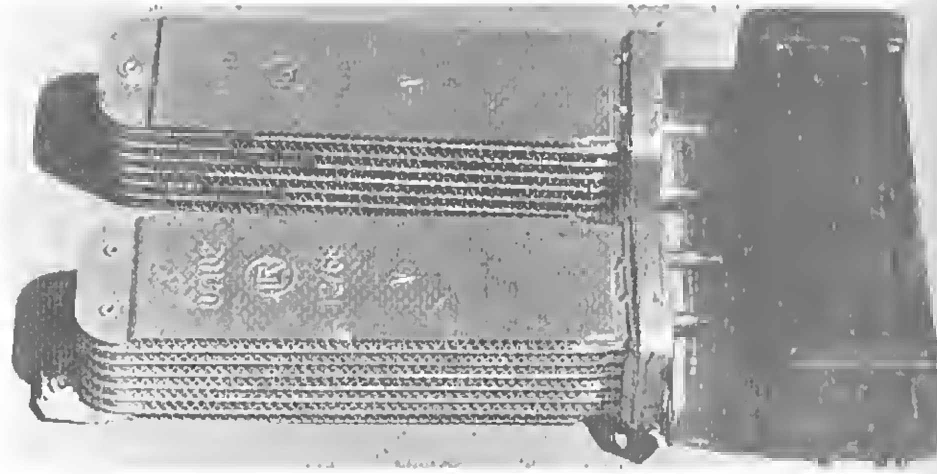




Effective cleaning of the VW block main oil passages requires removal of at least three aluminum plugs, to open all of the oil galleries to your brushes, solvents, steam cleaning or whatever. Other plug is at opposite end of case.



Plug pulled out of main oil gallery to clean case. Note crack which is starting in this case which had been bored for 92 mm cylinders.



Top left is early Porsche oil cooler, later cooler at left bottom and VW cooler at right. Note larger studs used to hold Porsche cooler in place, and upper stabilizing tab on latest Porsche cooler (fastens to fan housing to reduce cooler vibration).

OIL COOLERS

Porsche 912 oil coolers from 1964 through 1969, P/N 616 107 047 01, cost $43 each and are generally considered to be more efficient than the VW cooler. They will also stand more pressure than the VW coolers and are thus less likely to fail if a pressure relief valve should stick closed. Installing the Porsche cooler merely requires drilling two mounting ears on the crankcase to 8 mm or letter "O" size and counterboring these holes to 11/32-inch, deep enough for the cooler studs to seat in the crankcase. Ray Longanecker recommends that any oil cooler–VW or Porsche–be mounted with Loctite on the nuts. Nuts with built-in elastic locks can also be used, and these should also be used with Loctite. The cooler sits tall on the engine and tends to vibrate because of its length. This places a great strain on the studs and bolts which secure it to the crankcase. Double nuts can also be used.

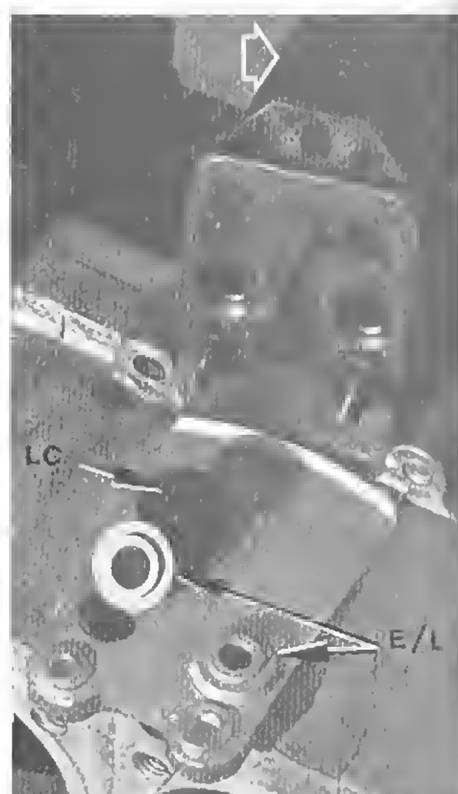
There are at least two kinds of Porsche coolers. The latest ones for use in the pre-912 A, B and C models, P/N 616 107 041 02, are secured at the top to the fan housing and use rubber insulators around the studs to help reduce some of the vibration which can cause the cooler to come off of the engine unless the studs are double-nutted and installed with Loctite. If you decide to use one of these, be sure to buy all of the mounting parts (insulators, washers, nuts and gaskets) at the same time.

AUXILIARY OIL COOLING & FILTERING

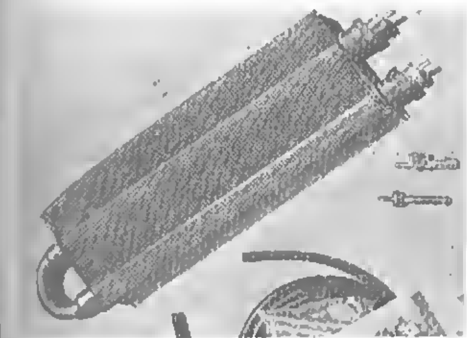
In addition to the full-flow oil coolers and filters which have been des-

Removing this screen (arrow), according to Vee builders, reduces fan resistance and gives more HP, as well as improving cooling-air flow to cylinders 3 and 4.

1970 VW replacement crankcase assembly, showing angle-hole adapter gaskets E/L which can be used to adapt early cooler (shown here) to late cases, or vice versa. Black adapter gasket LC has a large straight-through hole to use late cooler with late cases.



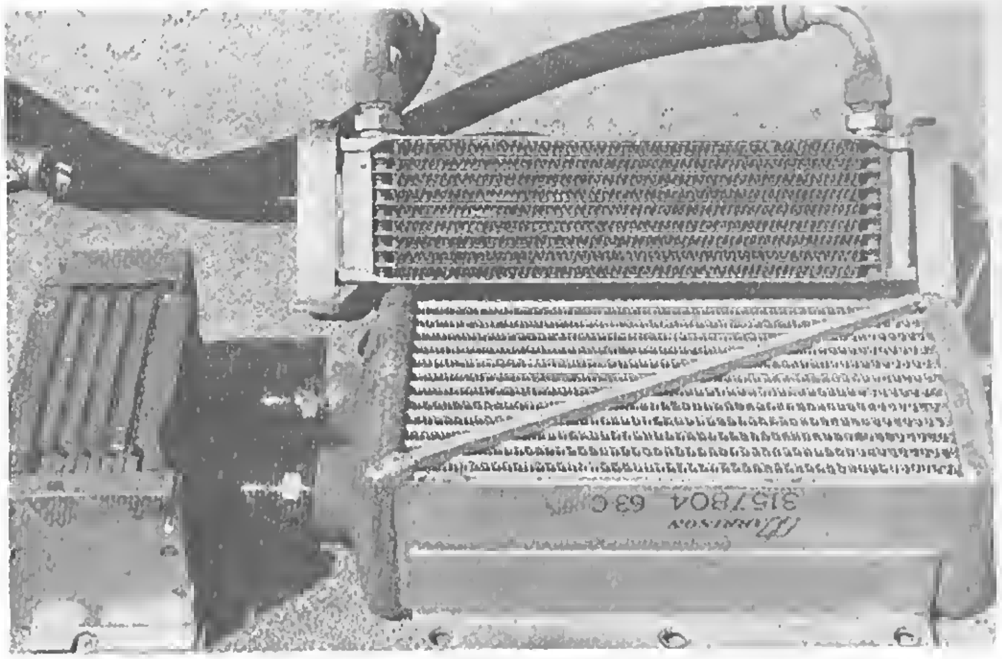
cribed, there are bolt-on kits which by-pass a portion of the oil-pump output through a filter and cooler and dump this filtered and cooled oil back into the crankcase. These kits can be installed without need for disassembling the VW engine. They would be most useful for an engine which is driven very hard in high temperatures because cooling and filtering even part of the oil should help the engine to live longer.



Hayden's by-pass oil cooler/filter kit is not recommended because it steals vital oil pressure and only cools a tiny amount of the oil. Cooler is large enough so that it would work well if used with larger hoses in a full-flow setup. Hayden's larger coolers are excellent for remote mounting.

Hayden and Thermo-Chem Oil-Cooler Kits sell for about $60. These have tiny hoses with 1/16-inch openings to restrict the flow through the filter and cooler because any larger opening on a by-pass unit would starve the engine's bearings. The built-in restriction provides self-regulation so that the cooler does not really begin to operate until the engine oil is completely warmed up—and thinned out.

Kits such as these are really only bandages or aspirins—they don't cure the problem and at best are for owners who are not knowledgeable about what is really required to cool and filter the oil. You certainly don't want to use one of these on a racing engine or an engine which you expect to live under hard driving conditions.

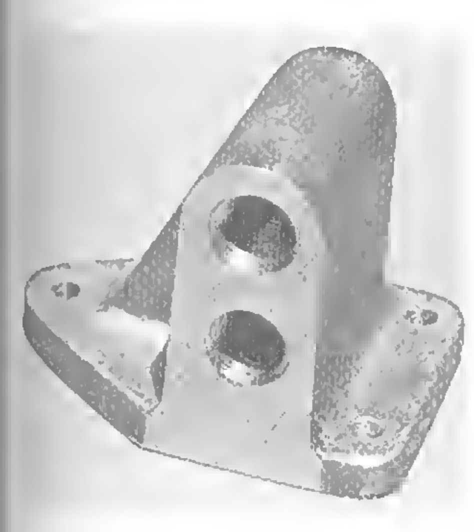


Three "stock" coolers of interest: at left, 60-62 folded-fin Corvair cooler—best ever offered for that car; right top, Triumph Spitfire cooler which you could probably buy for about $40 or less used; and below, highly-recommended-by-racers Harrison oil cooler—sold by Chevy dealers from the heavy-duty parts list for about $130.

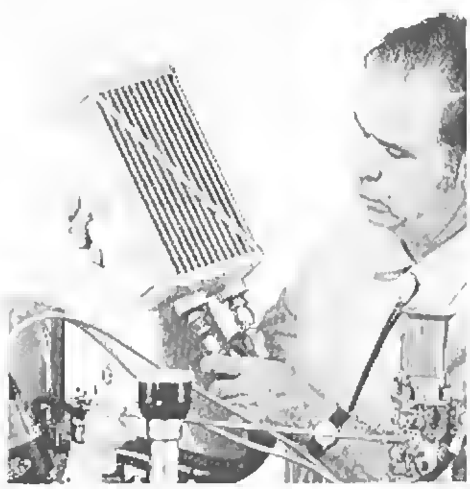
REMOTE COOLERS

If you are going to race your VW in hill climbs or road races, then improved cooling must be supplied by installing a large, remote-mounted cooler which is connected through 1/2" inside diameter or larger hoses. The hoses can be connected to an adapter manifold. The reason for the large lines is that oil is quite thick when cold and large lines ensure that the bearings will be adequately supplied under warm-up conditions. Before modifying the oiling system in any way, study the oiling system description in the VW 1300/1500 Service Manual, pages 13-14 and 39-43.

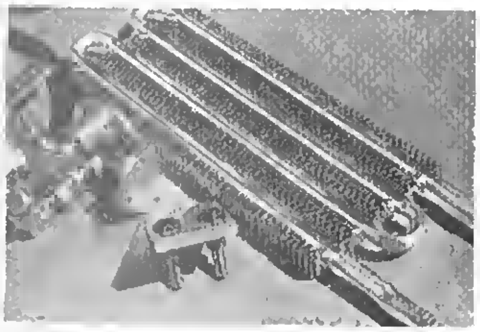
Adapters to connect the remotely mounted coolers are available from Competition Engineering, Race/Chek, EMPI, Berg, Thermo-Chem and others. Race/Chek's adapter block fits between the original oil cooler and the case. It is tapped 3/8-inch NPT to allow connection with a remote cooler in tandem



Stock oil coolers often crack at the mounting points, especially in high-RPM engines. Serious racers use a remote cooler and filter connected to the engine through an adapter such as this Gene Berg part. Competition Engineering and Race/Chek make similar adapters. Adapters connecting two cooler holes are used by drag racers who adapt a full-flow filter at the rear of the engine.



Bill Fisher installs a Harrison NASCAR-type oil cooler with Parker 261 steel-braid-reinforced 1/2-inch i.d. hose. Berg full-flow filter adapter installs without hoses, allows use with external cooler when required.



Thermo-Chem's "four-pass" cooler kit includes a full-flow filter adapter and a plate which replaces the stock cooler. Brackets provide for placing the unit in front of the engine air inlet, but it's better to get it away from the engine so that the cooling air won't be preheated.

with the stock cooler. Or, the stock cooler can be removed and the remote cooler used alone by installing pipe plugs in the tapped holes.

OIL COOLERS

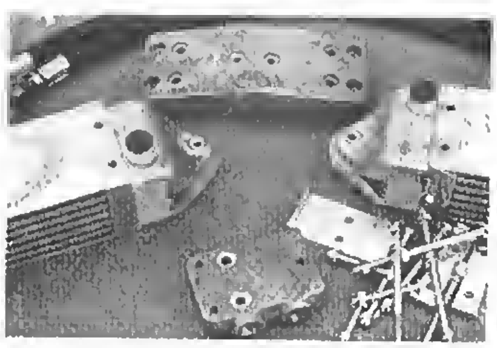
The best externally mounted oil cooler is the stock-car racer's model which Harrison Division of GM manufactures. Your Chevy dealer sells it for about $125 as Part No. 3157804. Mount it close to the engine to keep the lines short. Duct air to it through large-diameter flexible hose, or mount it so that air is forced through the cooler. The cooler may be mounted in an air scoop.

Other oil coolers can be used to cool your all-out VW racing engine. There is just one problem in choosing an external cooler for the VW. The cooler makers refuse to tell you which one will absolutely, positively work because they cannot control how you will install their coolers. That is, they have no way to insure that you will locate the cooler in a high-speed air stream. There are other variables which are beyond their control, such as the oil flow through the cooler, the oil-inlet temperature, and the ambient air temperature and flow through the cooler.

It is essential to include an oil-temperature gage in your system to keep track of what is happening. If you are experimenting with a cooler to determine air ducting, cooler size, etc., measure the temperature at the inlet and at the outlet of the cooler so that you can see whether the cooler is providing sufficient temperature drop for your particular installation.

The standard mounting ahead of the fan inlet on the housing – as used by Thermo-Chem and others – is o.k. when you use the external cooler instead of the stock cooler. In this location you can expect the external cooler to provide oil temperatures equal to that provided by the stock cooler – with the added advantage that number 3 cylinder will run cooler. And, an external cooler is almost essential if the engine is mounted solidly because this tends to destroy the stock cooler's mounting ears. To get the engine to run cooler than it will with a stock cooler demands the use of one very large cooler placed in the airstream, so there is a definite air pressure difference across it or fed cool air by a scoop – or two coolers with one located at the fan housing and another in the airstream. Above all, don't mount the cooler against a flat surface which prevents airflow through the cooler. Keep the cooler out of the way of rocks and dirt.

Do not attempt to use an automobile heater core for an oil cooler or disaster will surely result.



EMPI's oil-cooler kit uses two 311-type coolers mounted away from the engine.

OIL SUMPS: ARE SPECIAL ONES NEEDED?

A finned oil sump is an important addition to the high-performance VW engine. Fortunately, several authorities on engine construction have written a considerable amount of material. We can study the engineering facts to improve our knowledge.

P.E. Irving, in his excellent book "MOTORCYCLE ENGINEERING" (available from Autobooks in Burbank, California) has this to say on page 239: "While oil is good at collecting heat, it is very bad at getting rid of it again, because the layer directly in contact with a cool surface increases its viscosity and stays there, acting as an insulator and effectively preventing heat being dissipated from the hotter oil in the interior. Ribbing a sump which contains a quantity of oil is not very effective unless these are internal ribs also to transfer as much heat as possible from the body of the oil, but ribs placed on areas against which hot oil is violently thrown by centrifugal action can be made to radiate a lot of heat. In this connection, the polishing of crankcases, though pleasing to the eye, may cost as much as the whole of the machining and cuts down on the heat-radiating ability to a fraction of what it would be if the metal were left "as cast." You only have to look as far as your stove to notice that tea pots are polished to keep heat in—so why do the same to an engine?

Sectioned Berg magnesium sump shows post stiffeners which conduct heat from hot oil to cooled finned surfaces.

In another part of the same book (page 183) Mr. Irving says, "A polished surface emits less heat by radiation than a black one. Rate of heat emission from a polished surface is approximately one-tenth that from the same surface covered with a thin film of lampblack, and the emissivity of a cast-aluminum surface is increased about 10% by a thin coating of black paint."

Thus, a black surface is *ten times as efficient* as a polished one. ALCOA's Engineering Handbook indicates that Irving's comment is quite conservative. ALCOA compares an as-cast surface with one which has been black-anodized to a depth of 1.7 thousandths. The black surface is *more than ten times better in heat-radiating ability than a plain cast surface.* Remember these facts when you are tempted to start polishing and chroming various engine parts which can contribute to cooling efficiency.

Another noted mechanical engineer, Mr. Julius Mackerle, in his book, "AIR-COOLED MOTOR ENGINES," (also available from Autobooks) states that it is an error to assume that using a greater quantity of oil will reduce oil temperature. You'll note this claim in almost every ad for a large sump and it definitely is not true. He further remarks that "A finned sump does not aid cooling to any great extent as the oil does not flow down the cooled sump walls. Cooling is more intense on the crankcase walls, over which the oil flows in a *thin film* . . . Best oil cooling is obtained by a tube-type radiator . . ."

The reader should take note of the words "*thin film*" as these are the key to understanding the removal of heat from oil.

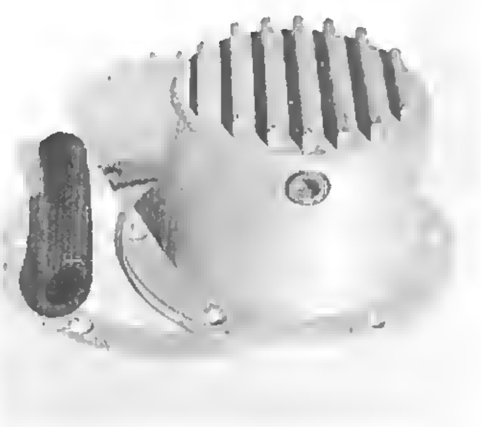
If you use the stock VW valve covers, do not chrome-plate them! Additional heat-removal capability can be added by welding or brazing sheet-metal fingers and/or baffles to extend into the hot oil to transmit the heat to the radiating surface. The covers are enamelled black as received from the factory. Refinish them with a *thin* coat of flat-black paint. The stock covers have quite a bit of surface area which you should use advantageously in helping your engine to rid itself of destructive heat.

Gene Berg says, "It's impossible to get gaskets to stay attached to chrome-plated covers. You'll have to destroy the chrome with a grinder to get the gaskets to stick in place. If you don't do this, the gaskets will creep and open up big oil leaks which can destroy your engine if they go undetected."

Crown Manufacturing recommends that you investigate aluminizing the fins on your cast-iron VW or replacement big-bore cylinders. Cylinders are sand blasted only on the outside fin area and then molten aluminum is applied by a high pressure aluminizing "gun" to give a thin coating with a satin finish. Improved cooling results.

Should you decide to use a special sump made of cast magnesium or aluminum, you will find several to choose from. Most of them can be installed while the engine is still in the car. An extension is added to the stock oil pickup tube so that oil is sucked from the bottom of the sump into the pump. The stock oil screen is retained. The extra sump adds about one and a half quarts to the VW's 5.3-pint stock oil capacity. This extra capacity can be essential for a VW which is drag raced, slalomed or encounters long sweeping turns, such as freeway on-ramps. What happens is as follows. The oil literally floods into the head which is on the outside of the turn and centrifugal force keeps the oil from draining back into the sump where it is needed. Enough oil can be held in the cylinder head, rocker cover and pushrod tubes so that the engine starves for oil before returning to a straight-line which would eliminate the centrifugal force and permit the oil to drain back into the sump. The bolt-on sump adds enough extra oil to permit holding the car in such a turn longer than it could be otherwise. However, it is wise to keep the problem in mind when negotiating long sweeping turns because one quart and a half provides only a few seconds additional safety margin. Oil contained in the extra sump cannot dump into the pushrod tubes. Most VW enthusiasts run just one extra quart with the extra sump to keep the oil level below the crank.

Additional oil capacity does not lower oil temperature—it merely increases the time required for the oil to attain a stable operating temperature: not usually of any real importance. Oil changes cost slightly more and the engine requires longer to cool off after it has been run. Additional oil capacity is helpful in a long race, providing the pickup is moved to the bottom of the bolt-on sump to make all of the oil available for use and so that the pump always gets the coolest oil. Additional capacity is insurance against losing an engine in the event that unexpected



Race/Chek bolt-on sump for Formula Vees has legal 250 cc capacity, comes with pickup tube extension and metric extender studs.

oil-consumption problems develop in a racing situation. Big-capacity sumps usually offer about 300 square inches of heat-radiating area, reduced to the equivalent of only 30 square inches if the surface is polished. In general, it can be said that an extra sump is essential for the VW engine being driven on streets, highways or dragstrips. The extra sump is not recommended for off-road use because of clearance problems . . . unless you install an adequate skid plate as described in our book, "BAJA-PREPPING VW SEDANS AND DUNE BUGGIES." When that extra sump is protected, it will provide additional insurance against losing an engine when hill-climbing or side-sloping.

Appearance. Most special aluminum and/or magnesium parts are purchased for looks instead of function—that is, show, not go! Do not let your desires for a good-looking engine confuse you when final-assembly time arrives. *Avoid polished fins!* If you are tempted to retain them, reread Engineer Phil Irving's comments. If you already have such parts, "de-polish" them by sand-blasting the polished surfaces. Black anodize the aluminum parts. Black anodizing is a plating process which many plating shops can provide for you at reasonable cost. Incidentally, the black obtained by anodizing may turn out somewhat spotty because castings do not usually anodize perfectly. This will not impair the heat-removal characteristics. Or, cover the exterior surfaces with a *thin coating* of self-etching flat-black paint of

Windage tray under crank is held in place by long stud extending into the case. Nut and washer hold tray bracket to the stud. Arrow points to capscrews which can interfere with oil-pump body.

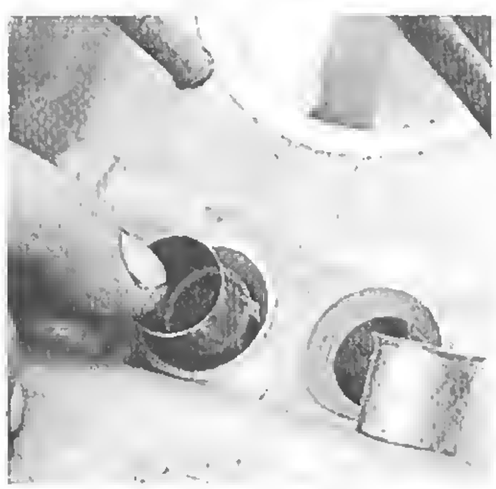
the non-insulating variety. Magnesium cannot be anodized. Although seemingly insignificant, these efforts will reward you with a cooler-running, longer-lasting engine. The same efforts should be applied to rocker-arm covers of the cast variety.

WINDAGE TRAY

Here is another money-saver—if you don't buy one. Stop to think about it: the VW crankshaft is pretty well out of the oil because the camshaft, tappets and contours of the crankcase provide a built-in "windage tray." Claims that the windage trays being sold today are able to keep the oil out of the pushrod tubes in hard cornering are just so much applesauce. Furthermore, all of the ones that I have seen—except home-builts—hit the camshaft. You'll note cutouts for the cam lobes in the one shown in an accompanying photo. A system of baffles is needed to stop oil from sloshing. If you choose to make a windage tray, consider including vertical baffles that run lengthwise (same direction as crankshaft) and crosswise. The tray must fit the case contours tightly when the case halves are bolted together. It should actually be gasketed to the case halves with neoprene material so that oil will be prevented from sloshing into the pushrod tubes in hard cornering. The pushrod tube extensions described in the following paragraph are far more effective at stopping oil from flooding into pushrod tubes than a mass-produced "windage tray" will ever be. Let your common sense win out on this one.

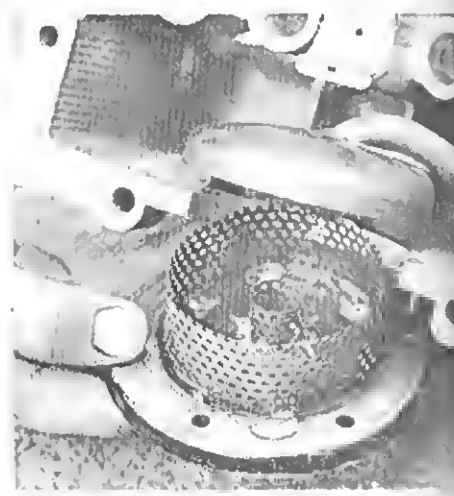
EXTENDED PUSHROD TUBES

3/4-inch-long pieces of pushrod tube pushed into each of the pushrod openings in the case and peened over are a great aid in keeping oil from sloshing into the rocker covers through the pushrod tubes in hard cornering. These do not prevent oil from draining back into the case, however.



3/4-inch-long piece of pushrod tube has been fitted into case and peened over at edge so it will be held in place by seal. These can be installed at all tappet locations to reduce the amount of oil which can slosh through the pushrod tubes into the rocker covers during severe cornering. This trick is used in almost all Formola Vees.

Dolf van Kesteren of F.A.R. Performance in Mountain View, California shows case fitted with windage tray and perforated-metal screen brazed to sump cover to insure positive supply of oil to pickup during hard cornering. He makes these modifications on his winning Vee engines.



CRANKCASE BREATHING

VW's made since 1963 include positive-crankcase-ventilation equipment. Models prior to that year could be so equipped, especially in certain of the states which are working mightily to correct the smog problem. These systems effectively remove harmful, oil-contaminating vapors from the crankcase.

thereby preventing corrosion and sludge formation. The use of these systems is very desirable on engines which are used for short trips or stop-and-go city driving. Keep the system clean and it cannot, contrary to common fictions, reduce performance at all.

Engines run in competition need additional crankcase breathing capacity to avoid the development of internal pressure which will blow oil past the seals and gaskets which close the engine. Of three approaches which have been used, two definitely do not work and should be avoided. If you want to cover the side of your engine with oil, mount one or more "big" breathers on each rocker-arm cover. Regardless of internal baffling or special plastic foam stuffing, no breather can hold back the flying oil mist which is inside of these covers. These covers contribute to the cooling of the engine because they are constantly bathed in a thin film of oil and the outer surface is exposed to cooling air. Adding a breather to the cover reduces the area available for cooling. The second non-working approach is the addition of a baffled tube to the oil-filler pipe. This tube is the recipient of high-velocity oil spray slung off the crankshaft. If you do not believe it, take off the cap while the engine is running. Wear your old clothes and have a can of GUNK handy to clean up the engine and its compartment! The stock breathing tube cannot be used, of course, because its tiny 1/2" I.D. creates high velocities of the escaping air/oil mist to carry out oil quite handily. The same is true of the dipstick tube which must be carefully gasketed or even plugged for competition to prevent oil from spewing out of that opening.

The reason all of the foregoing systems cannot work at high RPM is the fact that they provide openings with very small area. A satisfactory installation must provide adequate area to slow down the mist and sufficient length to permit the condensed oil to collect on the sides and drain back into the engine. Drag racers developed the answer with their catch-tank breather. A one-or two-gallon catch tank has a baffle in the center, with outlets in the form of two to three oil-filler-type breathers. Two 1-inch or larger rubber hoses connect the tank to the engine, usually to a steel tube brazed or welded into the front of the rocker-arm covers. A drain in the tank allows removing oil at the end of each run. Some of the 1970 Trans-Am pony cars (no VW's!) merely connect the two valve covers with 1-1/2-inch hose with a short piece of pipe in the center mounting two breather caps. This provides enough opening to slow the flow and allow the oil to drop out of suspension, draining back into the valve covers.

Part of the internal pressure and excessive oil mist can be eliminated by cutting two 0.090-inch-wide grooves to the bottom of the teeth (depth same as tooth height) in the center of the aluminum cam gear. This reduces the oil-carrying capabilities of this gear and cuts down the amount of oil which the gear can throw around. It picks up a bit of horsepower, too, because there is not so much oil to be squeezed out of the gear teeth as the gears mesh.

After reading this material on breathers, Darrell Vittone said, "I can only say that there is no substitute for good rings and cylinders. If these parts work well, elaborate breather systems are unnecessary."

IMPROVING THE OIL PUMP

Increasing oil flow reduces bearing temperatures. Thus, improving the oil-pump capability is a very desirable modification to make to the VW. In the first edition of this book I discussed converting auto-stick-shift pumps so that both sides could be used for a healthy volume increase. But numerous experiments made in 1971 showed that the stock single-section pumps could produce more output by blueprinting. As a result, I now recommend using a blueprinted stock pump designed for use with the passages in a particular block. For instance, 1970-72 cases and Universal Replacement Cases will have larger oil inlet/outlet passages than the earlier cases, requiring matching pump bodies.

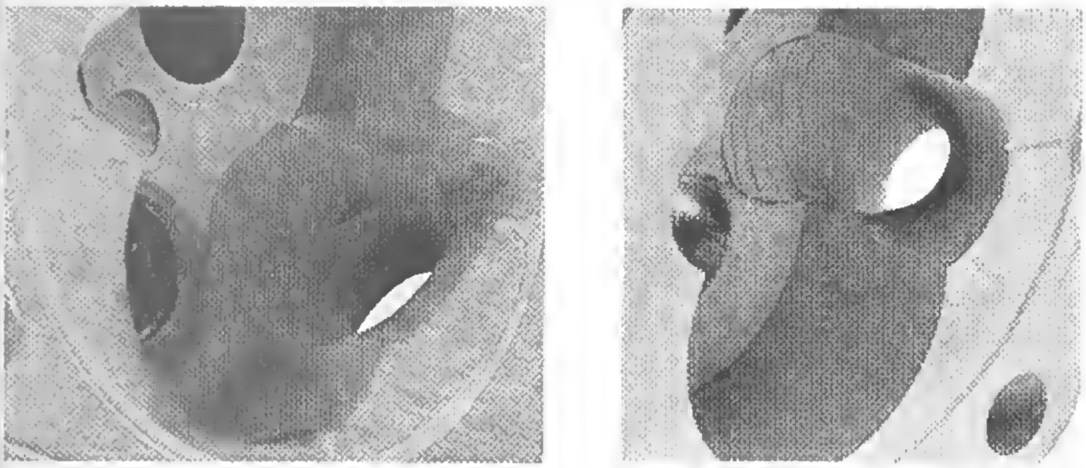
After mid-1971, VW engines were equipped with a longer-geared oil pump. It is similar to that used in the VW 411 engine. Gears are 111 115 123B and 111 115 115C; pump body is 111 115 107B. A different camshaft 113 109 027G (includes gear attached with *four* rivets) has a recessed gear 113 109 111B. The new pump cannot be installed in 1970-72 case or in the Universal Replacement Case unless the cam and cam gear are changed.

As with any oil pump, it is important to take the pump apart and deburr the gear teeth. When you think that you have the pump ready to install, assemble it in a spare crankcase and tighten *all* of the bolts. Make sure that the pump turns freely . . . *with your fingers.* If there are any high spots or points of roughness as you turn the pump, take it apart and find out why. Correct the problem and recheck the pump. Don't run a pump that is not completely free-turning. Installation of the pump is easily accomplished, even with the engine in the chassis. It is necessary to take off the pulley and rear sheet-metal shroud. Some extractor exhausts may have to be taken off, too.

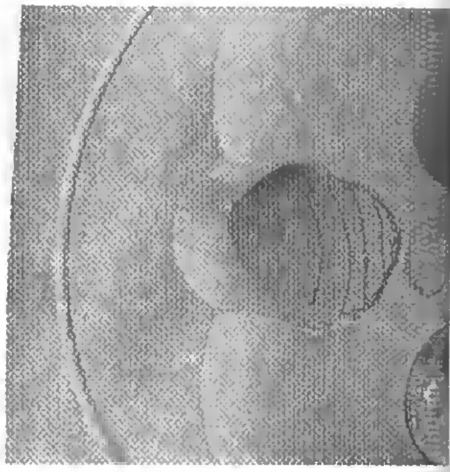
Pump Blueprinting by Gene Berg

During 1969-72, the Great Oil Pump Controversy arose. Many special pumps were offered to the high-performance VW enthusiast. I had an independent testing organization test every one of these pumps we could find. The conclusion: the stock VW pump which comes in the engine is large enough to do the needed job in almost every case. But, production tolerances may make a pump less efficient than it could be. I carefully miked 10 or more pumps at Chick Iverson VW to get two with minimum clearances: a small-hole pump (thru 1969) and a large-hole pump (1970-71). After reducing the end clearance to 0.0005 inch (and with no gasket) we tested the stock pumps. The 70-71 pump was a surprise. It primed instantly and increased its flow up to 6,500 RPM. The small-hole pump was down on flow and needed help. It was improved as was the 70-71 unit.

The 70-71 pumps have most of the needed improvements — but cannot be used in the pre-1970 cases because the larger holes in the 70-71 pumps do not match the small passages in the early cases and it may be impossible to get a prime or suitable oil pressure due to leakage.



Left, large-hole 70-71 pump with inlet area opened up and radiused toward bottom gear. Right, 61-69 pump inlet side opened up and radiused toward bottom gear as shown by pencil outline of modified area.



Outlet requires simple radiusing per penciled outline.

The things we did to blueprint the pumps for more output are described in the following paragraphs. Then we compared these with "high-performance" pumps. Results in the accompanying table show flow and inlet-restriction data that will be helpful in selecting any pump to replace a stock one.

The first step is to make sure that your pump can be blueprinted. Mike the O.D. to see that it is 2.755 to 2.7565-inch diameter. The maximum diameter is preferred to give a tighter fit – and better seal – between the pump body and case at the inlet and outlet holes. Next check that there is not more than 0.003-inch clearance between the gear teeth and pump body. Use a feeler gage here.

The pump gears and aluminum pump body must be smooth and free from scoring – as caused by dirt and grit going through the pump. The smoother the gear teeth and the body surfaces and the closer the fit between them, the more oil carried to the outlet by the teeth.

Shaft-hole measurement requires a micrometer and bore or snap gages. The hole should measure 0.504-inch maximum I.D. and the shaft 0.503 to 0.5035 inch. Clearance between the shaft and hole should be from 0.0002-inch minimum to 0.0015-inch maximum. Minimum clearance between the shaft and hole reduces oil leakage into the cam area.

If all measurements are under the maximum allowances, our next step is to reduce gear end clearance to 0.000 inch. Simply cross-file the pump body to flatten it to the depth of the gears. Do this with the gears installed. It takes a bit of skill to do this, so if you are not a machinist or die-maker, there's another way. Lay a piece of 180 or 200 grit Wet-Or-Dry abrasive paper on a perfectly flat piece of metal or plate glass. Flood the paper with solvent and work the pump back and forth with the gears installed until all of the surfaces are completely flat and in the same plane. Keep turning the pump body as you sand. We use a belt or disc sander. With the gears installed, we sand the pump body 1/4 turn at a time until it is obvious that the gears are also being sanded, thereby ensuring that no gear end play (other than provided by the gasket) will be present. Then we clean the pump and gears thoroughly and lay a gasket on a flat surface. We put the pump on top of this and push down hard on the body while making sure the gears turn freely. The sanded ends of the gears should be *lightly deburred* with a fine file.

Next we increase the intake-passage efficiency. The stock entry hole is aimed at the drive gear, tending to rob the bottom gear so it does less than its fair share. The area for filling the bottom gear can be cut back so that at least 1/2 tooth is exposed for filling when the top tooth closes off the entry area. The area under the root of both gears should be cut down to approximately the same depth as the inlet hole on the intake side. Radius the intake hole toward the cover and toward the bottom gear to help the bottom teeth in filling.

On the outlet side, radius the corners and clean out the bottom area of the hole. If you intend to use the pump with an externally mounted full-flow oil filter, plug the outlet with a 1/4-inch NPT plug of the socket-head variety. This requires drilling and tapping on the small-hole pumps, but only tapping on the large hole pumps. Or, you can use socket-head set-screws: 7/16 x 20 on pumps through 1969 models; 1/2 x 13 on 70-71 pumps. Use Loctite to retain the plugs because the threads will be minimal. A pump cover with tapped outlet hole must be used. See page 93 for a schematic of the necessary plumbing.

A pump with maximum clearances can be hard-anodized to build up all surfaces, thereby reducing clearances at the gear teeth, around the shaft and between the pump body and the case. Hard-anodized pump bodies are extremely resistant to wear, so the process gives double benefits.

As you can see from the flow data, the blueprinted pump's flow increases with RPM to match engine requirements. Inlet restrictions are kept below -5 psi and cavitation is avoided throughout the RPM range. No horsepower is wasted driving oversize gears which cannot be filled correctly from the largest holes available in a VW case.

Some high-performance pumps are well made. The Chipmunk is an exceptional standout for high-quality workmanship. When you are looking at pumps, take along your mikes, hole gages and feeler gages to check out end, shaft and side clearances *before you buy.* The first clue that a pump may have problems in priming or producing good flow is excessive end clearance and excessive clearance between the gear teeth and machined cavities. If the pump rattles easily when you shake it, you can believe that there may be no way to "save it." If there are grooves on the drive shaft and idler post, these tell you that there are lubrication problems inside the pump.

NOTE: No gasket sealer of any kind is ever to be used on the pump body where it enters the case or on the paper gaskets between the pump body and case and between the pump body and cover.

Type 3 Note - Oversize pumps may not fit ahead of the crank-mounted fan. If a hole is cut in the fan-housing casting to permit a larger oil pump to stick through, be sure that the new pump clears the front of the fan. Also, make doubly sure that you seal the housing so that no cooling air can leak out around the pump.

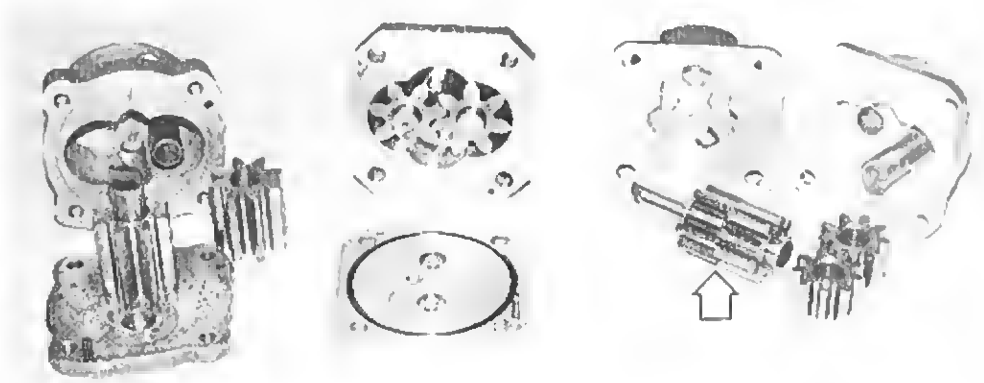
PUMP FLOW vs. INLET RESTRICTION COMPARISONS

Gallons per Minute/Inlet Restriction (-psi)

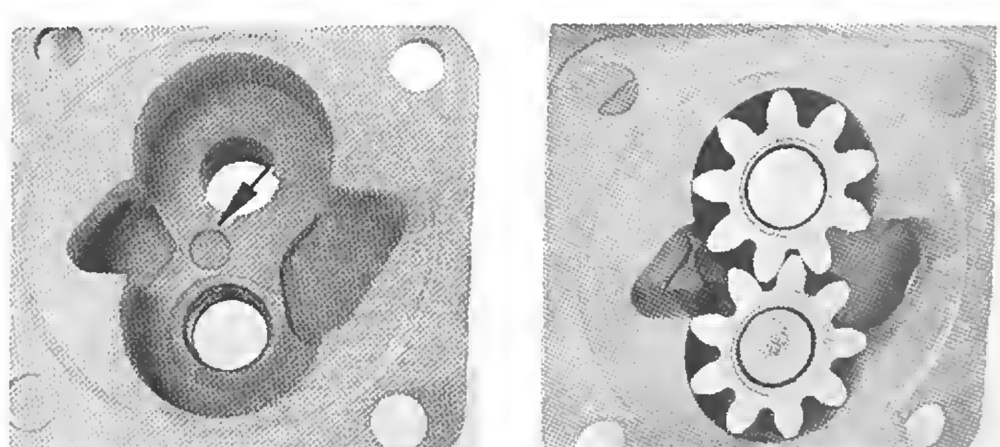
Engine RPM	61-69[1]	70-71[2]	Nickerson	Chipmunk
1500	1.20/1	1.68/.75	2.9/6	3.48/5
2000	1.50/1.25	2.25/1.0	3.28/9.25	4.32/6
2500	2.02/1.5	2.70/1.25	4.50/11	4.68/6.5
3000	2.58/2.0	3.24/1.50	5.02/13	4.92/7
3500	3.10/2.3	3.72/1.75	5.40/14.2	5.04/7.25
4000	3.60/2.75	4.02/2.0	5.44/14.5	5.16/7.5
4500	4.08/3.25	4.41/2.25	5.20/13-15*	5.25/7.75
5000	4.21/3.75	4.56/2.50	5.20/13-15*	5.30/8
5500	4.25/4.25	4.70/2.75	–	5.35/8.25
6000	4.30/4.75	4.80/3	–	5.40/8.33

* Cavitation at entry caused uneven delivery

1. Blueprinted small-hole pump. Small inlet hole creates greater inlet restriction.
2. Blueprinted large-hole (70-71) pump, hard-anodized for minimum clearances throughout.



Left: Nickerson 711 (Dura Bilt) heavy duty oil pump is big with rough fit and construction. Quality on these has been awful. Long shaft can't oil so idler gear can freeze up, destroying pump and/or engine. Right: Whitfield pump used add-on cover to house stacked stock gears with a stock pump body and had problems because of poor machining and quality control, plus non-pinned drive gears. Loss of prime with hot oil was an early problem with these pumps. This one failed when non-keyed drive gears spun on shaft, losing oil pressure and an 82 mm roller crank. Center pump is an absolute jewel made by Chipmunk. Solid aluminum billets are precisely machined and extra carefully fitted for tight radial and end clearances. O-Ring-sealed and dowelled cover supports two shafts. Idler shaft turns in counterbores at each end. Pump available with cover plumbed for full-flow-filter.



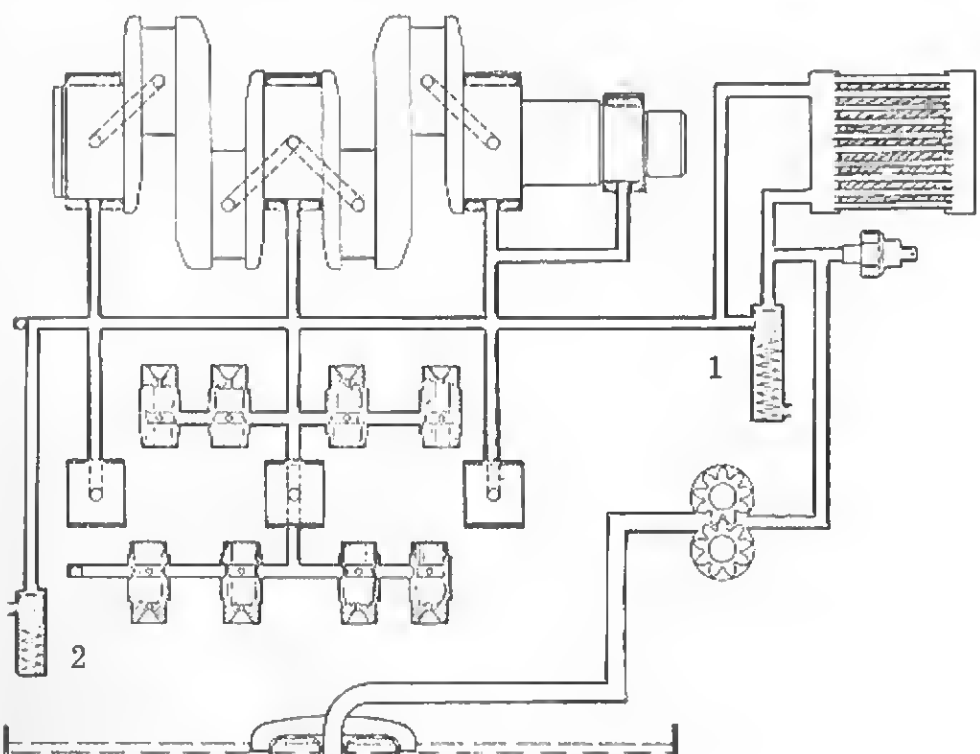
Two views of the blueprinted large-hole (70-71) pump showing areas opened up at gear inlet/outlet. Depression in bottom of pump cavity should not be disturbed (arrow).

Oils - Recommendations in the VW service manual call for SAE 30 straight-viscosity oil, that is, not multi-viscosity. All of the performance experts with whom I consulted agreed, but some of them use heavier oils — up to SAE 50 — in engines with large clearances. Valvoline seems to be the universal first choice of VW tuners.

One oil additive which can be helpful is GM's Engine Oil Supplement (E.O.S.)—available at GM dealers in 16 & 32 oz. cans. It is probably the best lubricant-additive that you can use in any new engine. With all of GM's research behind it—you can be sure that you're getting your money's worth!

Avoid other oil additives because they may not be compatible with the additives which the oil manufacturer has used. Always change your oil when it is hot to get the best flushing action.

Schematic drawing of oil circulation in 1970-71 VW case and in universal-replacement case. Oil-pressure-relief valve 1 directs oil to the bearings or to the cooler. Oil-pressure-control valve 2 keeps pressure at the crankshaft bearings at the same level (28 psi). Valve 2 opens only when pressure exceeds 28 psi to allow oil to flow back to the sump.



UNIVERSAL CASE

A crankcase with two relief valves is used in all 1970-71 vehicles. It is referred to as the universal case because only three versions are required to service the entire VW line from 1200 through 1600 cc engines. One case fits all 40 HP engines of the types imported into the U.S., P/N 111 101 025 C. All 1300/1500/1600 engines in Type 1, 2 and 3 vehicles (except Type 3 Automatics) are serviced with P/N 113 101 025 E. Type 3 Automatics use P/N 311 101 025 H. A different oil-pump body is used and it has a thicker cover. The body has larger inlet and outlet holes to match the larger passages in these cases—typically 2 mm larger (0.078 inch).

Although adapter O-rings allow mating your old oil cooler to the larger passages of the new case, new oil coolers with larger openings are available for all Type 1, 2 and 3 engines. If you have a Type 1 or 2 engine, convert to the 1971-style fan housing and cooler mounting with a late Type 3 cooler. This separates the cooler from the air flow to the left side cylinders so that they will get their fair share of the cooling air. Or, take the cooler out of the housing entirely for the same reason.

VW lists new crankshaft pulleys which have hubs 2 mm longer than the older ones—probably to clear the new oil-pump covers. However, I know VW owners who are using their old pulleys in the new cases. Bear in mind that you could have an interference problem at this point.

When you buy a new case, the VW dealer will have a list of the extra parts that you will need to make the conversion.

The case will make your engine about 1/8" longer, so watch for clearance when you install your engine.

Camshaft & valve train

understand what's happening before you change it

Because the camshaft is one of the last things to fall out of the engine during disassembly, it is also the last item which should be changed when chasing after additional power. By the same token, it needs very careful installation to ensure that maximum benefit is obtained from its action. The camshaft is only part of the valve train and the other items deserve equal attention if utmost performance is to be achieved. Lifters, pushrods, rocker arms, spring retainers, and valve springs interact in ways which are not completely understood by many mechanics. Installation techniques are also important because they affect camshaft life. The coverage devoted to these related parts and to careful installation will seem over-long to the casual reader, but the devoted engine builder will recognize that a short presentation does not give the complete picture.

Several camshafts have been offered in stock engines. They are not impressive from a lift or duration standpoint, but are well mated to the stock engine. Grinders of special cams can help. A detailed discussion of effective valve opening, as well as timing graphs relating stock cams to reground ones, will dispel some of the hocus-pocus surrounding the entire subject. Valve spring and retainer information is also included with specific directions for checking and changing camshaft timing at installation. Rocker-arm geometry and its effect on valve lift and guide wear is fully covered. The reader who follows all of this information with great care will discover that his engine has suddenly gained "free" horsepower—and that is the best kind!

HOW THE CAMSHAFT WORKS

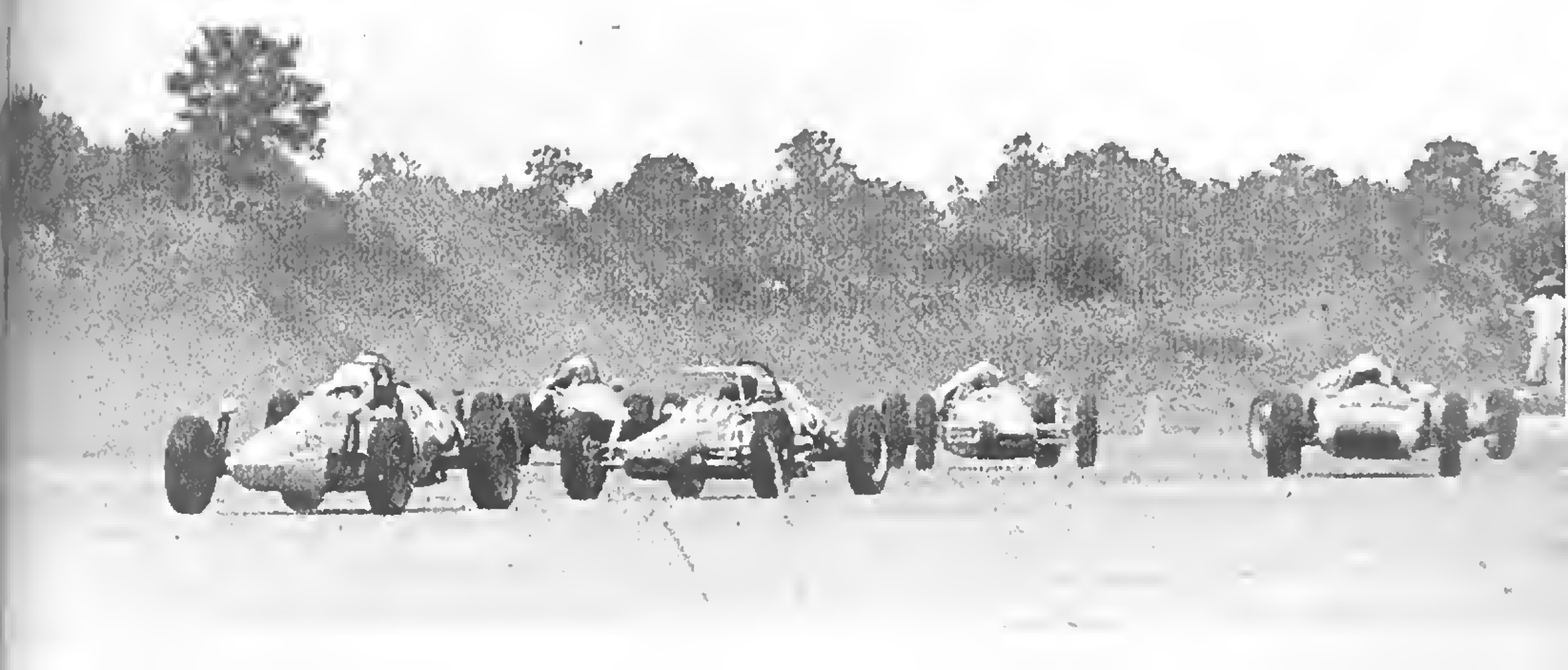
It looks like a simple stick with bumps on it, but the cam is the major controlling element in determining your engine's ultimate behavior. The stock camshaft is carefully related to a fantastic number of factors, including carburetor area, compression, displacement, transmission and axle ratios, car weight, performance desires, driving habits of the buying public, and so on—ad infinitum. You and I cannot relate these factors to the same fine degree as the factory engineers with their experience and computers. We can consider what goes on during the intake and exhaust operations in a single cylinder.

Valve timing is nearly always related to degrees of crankshaft rotation, but avoid this oversimplification. Another relationship is more helpful in describing camshaft functioning: valve action versus displacement of the cylinder. Where is the piston and what is it doing?

As high-school students we were taught four-stroke internal-combustion-engine functioning in four unrelated 180-degree segments: Intake, Compression, Power, and Exhaust. If the valve mechanism could slam the valves open and shut precisely at the TDC (Top Dead Center) and BDC (Bottom Dead Center) points without delays, the engine would probably run—until some part broke! But, just as instantaneous valve action is impossible due to the severe forces such would impose on the valve mechanism, instantaneous movement of the intake and exhaust gases is impossible. So, the 180°-segmented description of valve opening versus crankshaft position does not work outside of the textbook covers. Now that another school-boy belief has been destroyed, let's look at the practical facts of the matter.

The intake valve is opened *before TDC* while the piston is still rising on the exhaust stroke. There is not much pressure left in the cylinder at this time and the early opening is added to the textbook's 180°, even on "mild" engines. Early intake-valve opening gives the valve a "head start" on the movement of the piston. The valve must be limited in its rate of acceleration so the cam designer starts it moving early to cause it to be fully open before the piston reaches its

Bobby DeMarco leads the pack out of a corner in an SCCA Regional Formula Vee Race during 1970 at Sebastion, Florida. Car is a Race/Chek-prepared Beach.



point of maximum acceleration, or the gas flow will be impeded by a partially open valve just as cylinder displacement is being increased at the most-rapid rate. That's exactly what happens with the stock VW cam. The designers open the intake at almost TDC so that they can make the tiny engine give both economy and low-speed torque beyond what you'd ordinarily be able to get. Early opening is often touted as a cleaning device for pushing the exhaust out and helping to clean up the chamber of spent gases. According to Racer Brown, this may be true of a hemispherical chamber with a tuned exhaust and intake system, but it certainly does not apply to Volkswagen's wedge-shaped chamber. Early opening in the VW should be approached with great care because the incoming gas has a decided tendency to do an "about-face escape act" through the convenient exhaust valve opening. All you get for your efforts is increased fuel consumption, plus a few other disadvantages, and perhaps a bit of exhaust-valve cooling by the escaping fresh mixture. As you increase the number of degrees that the intake valve opens ahead of TDC, the intake system is confused at low speeds. Early opening, therefore, is the culprit causing the rough-idle trademark of a high-RPM engine. While early opening causes no particular problems at high speeds which provide an atmospheric-pressure operating condition, reduced speeds cause manifold vacuum to suck exhaust gases into the intake system. The results are diluted fuel/air mixtures, rough idling, spark-plug fouling in extreme cases, and fogging of the mixture out of the carburetor or injector throats. This dilution is one of the reasons why an accelerating racing engine will tolerate full ignition advance at very-low RPM.

Just as we added to the opening side of the 180°, the same must be done at the finish. There is good reason to leave the valve open *after* BDC to take advantage of the incoming-gas momentum. Although the piston can be said to be starting its upward stroke after BDC, the truth of the matter is that it is barely moving upward for quite a few degrees. The crank swings through a considerable arc to swing the connecting rod big end sideways. The momentum of the inflowing gases gives additional filling during this period of piston "laziness," up to the point where reverse pumping begins. As piston-acceleration rate increases, the intake valve must be closed or severe reverse pumping and charge-density reduction will occur. It should be obvious that as engine RPM is increased, the closing point can be left until later than is desirable on an engine which has to produce good torque in the low and mid range. A tuned-intake system will increase charging-mixture momentum to improve cylinder filling in a limited RPM range. Reverse-pumping of the charge back into the manifold, as caused by late closing, is one of the factors allowing modern-day super-stock engines to be set up for drag-race competition with much higher compression than would ordinarily be possible with gasoline for fuel. The same cars would require lower compression if set up for continuous high-RPM operation, unless running at high altitude as at Bonneville.

Exhaust-valve operation can almost be deduced from what you have read about the intake. Because the exhaust valve needs its "head start" on the piston, a part of the power stroke is subtracted from the 180° example by opening the valve *before* BDC. This releases pressure from the cylinder so the piston works less to pump out the gases, and ensures that the valve is fully open by the time the piston is accelerating at its maximum upward rate. Pressure "blowdown" also starts the exhaust-gas flow out of the cylinder. Strangely enough, little power is lost by early exhaust-valve opening because the burning gases impart most of their available effort to the piston in the first 90° of the power stroke. For this reason some cams, including VW's, are ground with dual patterns to give more exhaust than intake duration. When closing the exhaust valve *after* TDC—the intake action is overlapped—both valves are open at the same time. If this overlap is stretched too far, serious dilution occurs, especially past 70° overlap. When a tuned-exhaust system is used, late closing of the exhaust takes advantage of the momentum of the leaving gases to help discharge the cylinder. It is sometimes possible to reduce cylinder pressure on a momentary basis to below atmospheric (vacuum) so the incoming gases are started in by the draft of the exhaust gases, as well as by the increasing displacement afforded by the descending piston.

While the foregoing can be interesting in understanding the operation of your engine, it would not enable you to tell the cam grinder the precise number of degrees of overlap and duration which you would need for specific applications. Fortunately for most of us, the cam grinders use their superior knowledge of mechanical limitations and the physics of gas flow to protect us from ourselves. They have cam patterns for every situation. You cannot

Mark and Paul Schley's EMPI-sponsored Lightning Bug I was totally demolished at Bug-In 3 where it "flew" into the guard rail. It's shown here at weigh-in at AHRA Drags in Fremont, California in 1969. Lightning Bug II campaigned in 1970 with ET's of 11.52 and 113 MPH as "H" gasser—12.35 and 107 in "I" Gas Class.

go far wrong by relying on the recommendations of qualified and capable cam grinders, especially if you are willing to follow through with careful installation procedures as will be described.

STOCK VALVE TRAIN

VW's valve train is nearly identical to that which has been thoroughly proved in hundreds of different engine makes. An aluminum gear-driven camshaft of cast-iron alloy with four lobes (lobes common for opposing cylinder pairs) runs in split bearing shells in 1300/1500/1600 engines, and directly on bores in the crankcase halves in 1200's. Lifters operate in holes bored in the cases. Tubular-aluminum pushrods reach through rubber-ring-sealed oil-return tubes to connect with rocker arms in the "tub" shaped section atop each head. Each forged rocker arm pivots on a shaft. Adjustment is by a threaded ball-ended screw in the valve-stem end of the rocker arm. Camshaft motion is multiplied by 1.1:1 (1:1 on 1200's) by the rocker arm which contacts the tip of an intake or an exhaust valve. Valve diameters are described in the cylinder head chapter.

Valve stems are 8 mm diameter, approximately. Seating pressure of 126 lbs. for each valve is provided by a coil spring. Springs are retained by stamped-steel retainers weighing 14 grams each and wedged to the valve stem by one of two valve-key styles. 1966 and later retainers are better parts for race application than previous ones. Although the weight is just a tiny bit more than aluminum retainers, their extra strength and low cost makes these the parts to use for most engines. The valve mechanism is sealed off by a stamped-steel cover which forms the outer half of the enclosure. Constantly bathed in a thin film of oil, these covers significantly aid in cooling the engine.

NOTE — Camshafts used from mid-71 on may have gears retained with four rivets instead of three. These gears are recessed to allow for the greater depth of the 411-style pumps used in these late engines. See oil-pump section for more details.

STOCK CAMSHAFTS

The following table indicates model, intake opening and closing, exhaust opening and closing, and lift in inches. Opening and closing figures are in degrees of crankshaft movement.

MODEL	TIMING & LIFT (Intake/Exhaust)	DURATION
1200	4-32/41-1 0.297/0.285	216/222
1200A	6-35.5/42.5-3 0.297/0.285	216/225
1300 1500 1600	7.5-37/44.5-4 0.322/0.310	224/228

All checked at 0.040" valve clearance.

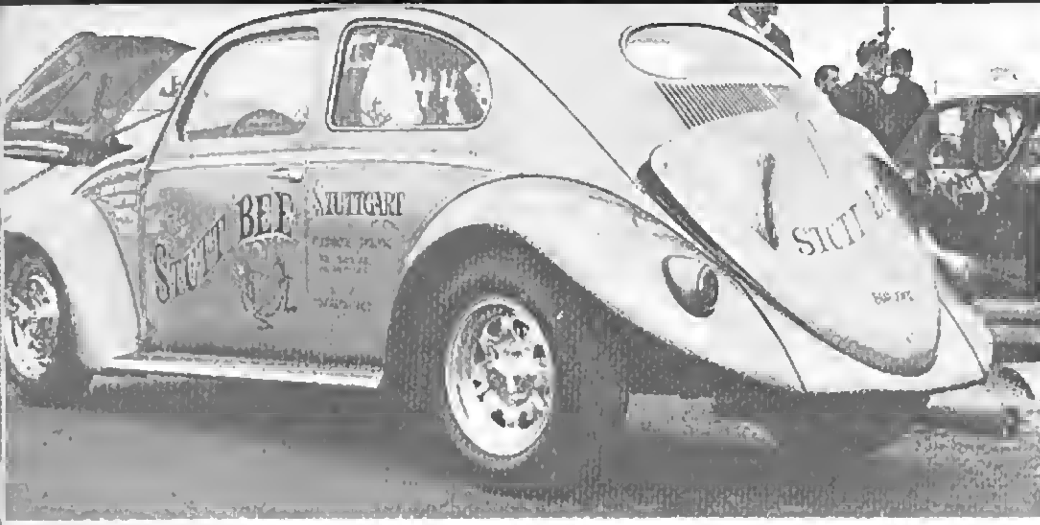
As is the case with any production-made part, VW camshafts vary greatly due to tolerances which must be allowed or the factory wouldn't produce many cars. For this reason, Vee builders are extremely careful in selecting their camshafts out of the parts bins. The stock grind which they put on each of the lobes ensures that they get all of the lift and duration which is allowed, and typically adds 1/2 to 2 horsepower!

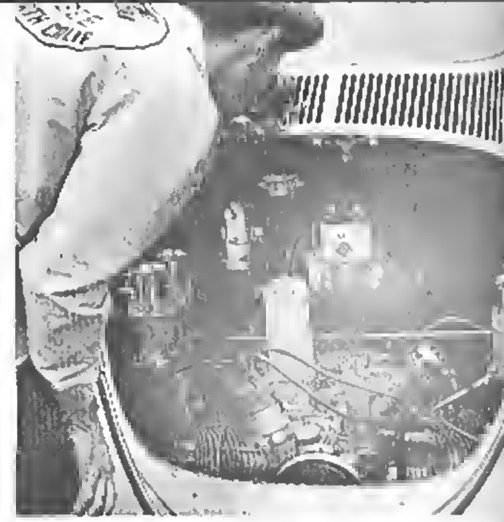
Stock cams which I have measured varied from 0.290 inch to 0.305-inch lift on intakes (at the cam) and from 0.280 to 0.290 inch on exhausts (also at the cam). This averages to 0.297 for the intake and 0.285 for the exhaust. Tuners who have measured hundreds of cams in their search for the best ones could probably tell you of even wider variances.
These figures can be used as the typical lift for a 40 HP engine (minus running clearances) because those have 1:1 rocker arms. The 1300/1500/1600 engines have 1.1:1 rocker arms, so you can expect lifts of 0.322 for the intake and 0.310 for the exhaust. Adapt 411 rockers with offset shafts and their 1.3:1 ratio gives 0.383 and 0.366 lift. Add a set of 1.4:1 rocker arms and the lift jumps to 0.402 and 0.396, respectively, for the intake and exhaust.

Most magazine articles tell you to ashcan the stock camshaft. More baloney. If it is so bad, howcum so many million VW's manage to get their owners to where they are going every day? The stock camshaft is often the perfect answer if you want to be able to slog along hour after hour at low RPM's—as you might want to do in traffic, or cruising the dunes or running anywhere off-road except in a race. When you start cranking in the extra duration, the engine begins to get what I call a "soggy bottom." You have to scream it up to get enough torque to pull the skin off a rotten banana, then the torque comes in "like gangbusters," usually when you don't really need or want it. That kind of engine behavior is strictly all wrong for the street or off-road application, so think twice—or maybe even three times—before stuffing a wild lumpstick into your buggy or off-road sedan or grocery getter. Buy a decal instead. They are cheaper than a cam kit anyway. If it makes you feel better, tell your friends about your "wild" camshaft and drive on by with your car in high (close-ratio, of course) gear and your little watch-winder engine going "pocketa-pocketa-pocketa." Happiness is often a stock cam.

If you are going racing or want exceptional performance for the street, the camshaft may need some attention—if you are paying some additional attention to the cylinder heads or installing the dual-port heads. Don't consider installing a special camshaft unless you also increase the carburetion. If your engine is a 40 HP, proceed with caution, considering only a very mildly reground camshaft in conjunction with ported heads, big-bore kit (82 or 83 mm), and a centered two-barrel carb such as a Carter or Holley, or a Zenith with 24 mm venturis.

Look at the lift-data charts in the cylinder-head chapter and you'll note that the stock single port head, even with 35.5 intakes (larger than 40 HP) and you'll note that the stock camshaft lift is well mated to the flow characteristics of the head—a happy combination, as it were. If you insist on installing a camshaft in any single-port-headed VW without making other modifications such as a big-bore kit, porting the head, etc., the chances are good that the engine will run so poorly that you'll promptly tear





"Stutt Bee"—top-running VW sedan turns 11.61-second 1/4 miles, with 112 MPH speed. Engine produces 169 uncorrected horses from 92 mm pistons driving 82 mm SPG roller crank. Car weighs 1171 pounds due to severe dieting. Tube front axle is used. Propped-open engine lid is standard drag-race costume. Audley Campbell, VW specialist who owns Stuttgart Motors in Chatsworth, California, also owns—and drives—this potent machine.

the poor thing apart again to reinstall the stock cam. Those are harsh words, I know, but they have been proved time and again by VW owners who just couldn't believe the real facts of life. An engine equipped with a dual-port head is something else again because these heads start out with intake breathing capacities equal to the best you can get out of the single-port with a lot of work.

So, don't put a reground camshaft in a VW unless you have done something else to the engine to allow the engine to breathe. Otherwise, you will have an engine that runs like it is having an asthma attack.

RACING CAMSHAFTS

Perhaps the best way to start examining the subject of racing cams is to let W. G. "Racer" Brown talk to us. Well known for his Porsche records at the Bonneville National Speed Trials in the early 60's, Racer has transferred this expensively obtained air-cooled-engine experience to the VW.

He says, "Don't go wild on VW valve timing because of small cylinder displacement and also because of manifolding and porting problems. Keep *effective* duration about 280 or 285 degrees as a reasonable maximum, with around 260 or so for street applications, particularly on the inlet side. The exhaust can stand additional duration which will not detract from overall performance. Generally, valve lift should be in the range of 0.400 to 0.450 inch. Higher lifts will not show up as well as on other engines because the valves are not too badly shrouded by combustion chamber walls, adjacent valves, etc. Entry and exit to and from the combustion chamber is no particular problem—upstream of the inlet valve is where the real problem lies, especially on single-port heads."

Racer continued, "There is no *effective* timing until the valve is off its seat at least 0.015 inch to establish flow. It is easy to get added duration for advertising purposes by adding in the lengthy ramps which must be included to lift the cam gently off of its seat and return it the same way . . . gently! When the *effective*-timing yardstick is applied, stock VW cams show room for improvement."

The secret of camshafts which have been reground for additional performance is laid bare by lift vs. crankshaft-movement plots. Remember, too, that duration cannot be considered separately from overlap. The following table compares popular reground ones on the basis of effective timing; that is, with the opening and closing measured with the valves approximately 0.015 inch off their seats.

Lift vs. crank-degree diagrams will look similar for various cams because the designers must all work within the same limits for valve-train accelerations, spring pressure for returning the valve to the seat, and compatibility of the tappets with the camshaft lobes under the spring loading, lubrication, and temperature conditions which exist. The rate of lift and descent, and therefore the curve shape, will turn out to be decidedly similar on various camshafts, provided the engineers know what they are doing. Be wary of vastly different curve shapes.

When comparing camshafts do not be impressed or swayed by a few degrees difference in timing or several thousandths lift. Such minor differences will not make two similar cams run that much differently.

If you plan to take apart the crankcase to install a crankshaft or do a complete rebuild, order your camshaft ahead of time. The grinders turn out dozens of V-8 cams for every VW that runs through their factories and a delay of a week or two would not be unusual in getting a VW cam. Cam grinders today do not usually regrind old camshaft cores, but choose to use new parts instead.

Get the grinder's recommendations as to spring pressure so you will be able to install the appropriate springs. It is safe to assume that you will be asked to discard the small-diameter VW springs which will require machining the spring seats in the heads to accommodate the larger springs. Remember this when having your heads machined.

ROLLER TAPPET CAMSHAFTS

VW's crankcase design does not lend itself to simple installation of a roller-tappet camshaft. There is not enough space for the guiding devices required by most roller tappets. Also, the usual roller tappet has a large notch in which the needle-bearing roller is installed. This gap would create a mammoth oil leak from the main oil galleries . . . which supply both the tappets and the crankshaft. For this reason, no roller-tappet cams are made for VW.

CAMSHAFT GEAR

VW camshaft gears have different diameters to accommodate different center spacings between the centerlines of the crankshaft and camshaft. This difference in gear adjustment allows the VW factory to adjust gear lash with the centerline spacing differences which occur as a normal variation in production tolerances on the cases. In general, the marking on the cam gear and the cam gear lash or "slop" should be observed when you take the engine apart. Then, if the lash was o.k. and you replace the cam gear, use one with the same marking. If there was too much lash, a larger diameter gear can be installed to take up the play. VW shops which do a lot of this work keep all of the cam gear sizes on hand so that they can set the lash exactly.

The factory rivets the gears onto the camshaft, but some cam grinders drill and tap the factory rivet holes in the cam hub and use capscrews to hold the gear in place probably because this is familiar practice in U. S.-made engines. While there's no difference in strength or longevity of the two methods of securing the cam gear, the capscrew method makes it easy to swap gears to get the right lash.

TAPPETS (valve lifters/cam followers)

Regardless of what you call these parts that convert the rotary motion of the cam lobes to a linear motion for the valve opening and closing, they are extremely important . . . and deserve more than a passing mention.

The camshaft and lifters must be "compatible" or extremely rapid wear results. Why? Because the force of the valve spring, multiplied by the rocker arm, works to keep the tappet in contact with the cam lobe. This force squeezes out and wipes away the lubricant, thereby promoting wear. Unless the metal types of these rubbing parts are exactly compatible in metal composition, hardness and surface finish, very fast wear can result. VW—and a lot of other car makers—have occasionally had camshaft/tappet incompatibility problems which create trouble. The worst incidence for VW was with the two-piece parts used on the 1200 engines from their introduction through the 61 models.

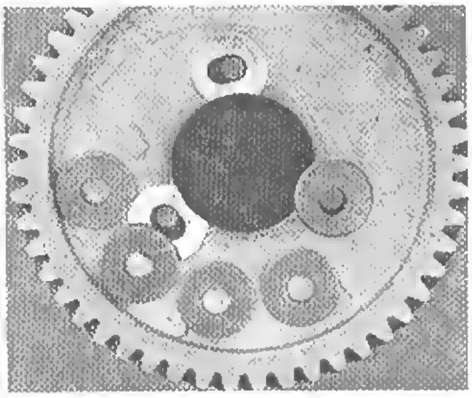
CAM COMPARISON TABLE

Type	Duration	Lift/Rocker 1.1	1.3	1.4	Valve Timing IO	IC	EO	EC
Racer Brown								
25A	266°	.356	.422	.454	27	59	63	23
ST-22	276°	.369	.436	.470	32	64	68	28
STX-21	306°	.408	.482	.520	50	76	80	46
STX-23	315°	.418	.494	.532	55	80	85	50
Engle								
110	284°	.429	.507	.546	36	68	72	32
120	287°	.450	.530	.573	39	68	74	33
125	300°	.455	.537	.578	44	76	80	40
140	316°	.473	.538	.602	54	82	86	50

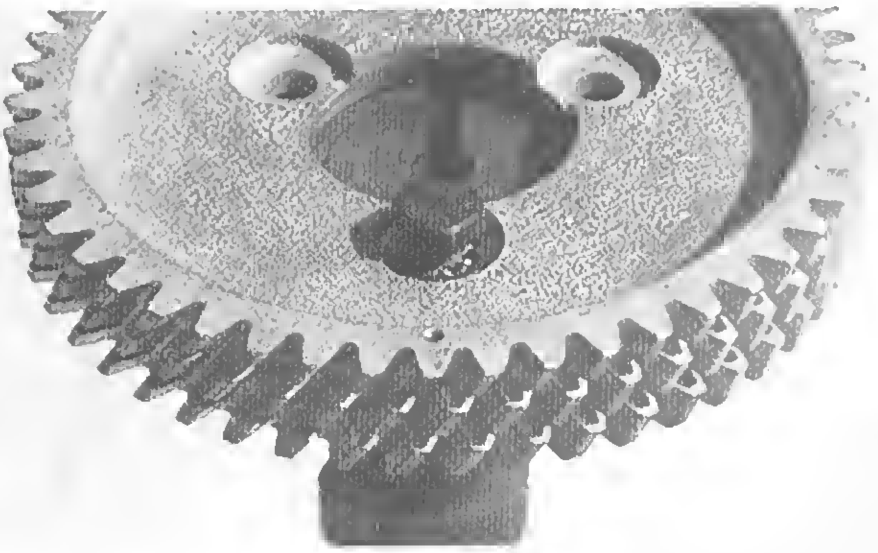
NOTE: This table is far from complete. It does not list all of the cams supplied by either manufacturer, and there are many other cam grinders supplying camshafts for the VW engine. Lifts are in decimal fractions of an inch.

By 1962, most of the cam and tappet problems had been cured with a one-piece tappet which, although heavier, is compatible with the stock camshaft and any cam which is reground on a stock cam core.

Tappet faces are not flat, incidentally. They must be slightly convex with about a 30-inch radius. This is done to make the tappet turn as it works against the camshaft, thereby constantly exposing a new surface under the load so that the cam lobe and tappet will not wear out in a hurry. So, don't face tappets flat with a valve facer or you'll be rebuilding your



BerGear allows adjusting cam by merely removing oil pump. Offset washers advance or retard camshaft as required for fine tuning.



For people who take things apart without thinking about how they'll get them back together again: this photo. When installing the cam gear, keep the cam-gear dot lined up with the slot in the cam end. Hole "under" dot matches cam hole at end of slot. Two 0.090-inch-wide grooves cut to tooth depth are Gene Berg mod to reduce oil slung about by cam gear. This can add horses by reducing power required to squish oil out of meshing gear teeth.

engine. You can quickly check whether tappets have the desired curvature by holding the faces of two tappets together. They should "rock" and if they have "gone flat" -get new ones.

If tappets have a few small pits in them—without any swirl marks, radial lines or other evidence of excessive wear—it's o.k. to use them again. But, you'll have to install them "back home" against the same lobes of the old cam, right where they ran originally. If you are installing a new cam or a reground cam, spend the money for a new set of genuine VW lifters (or use the lifters recommended by the cam grinder). You'll be glad that you did. Lubricate the cam and lifters carefully as described in the engine assembly chapter. Hydraulic tappets are not recommended for pre-1970 VW's because the low oil pressure at idle in the earlier engines allows the lifters to collapse. I'd guess that VW will eventually install hydraulic lifters as stock items because of the quiet running which they give—and because hydraulics can compensate for the vast clearance changes which occur as the engine expands and contracts.

INSTALLING THE CAMSHAFT AND FINDING TDC

You will need a degree wheel such as the pulley made by Santana, a pointer, and a one-inch-travel dial indicator with clamps and brackets. Make sure that the crankshaft halves are cleaned. Install the main and cam bearings in each crankcase half.

If you are building a high-RPM engine, buy two sets of camshaft bearings so that you will have a full-circle thrust bearing by using the flanged thrust bearing half out of each set. The stock engine has a flanged bearing in the left half of the case only.

Now a slight modification must be made to two of your old valve lifters (tappet). The lifter needs a flat surface on which the stem of the dial indicator can ride for the following checks. A length of aluminum or steel rod can be fitted into the lifter body and a flat face turned on it. Don't use the radiused cup of the lifter as a contact point for the indicator stem, as it can cause inaccurate readings and possibly damage the indicator. Install the two modified tappets in the lifter bores for No. 1 cylinder.

Before installing the camshaft, especially a reground or billet camshaft which has been Parkerized, check both of the thrust surfaces by the camgear end. Remove any rough spots by polishing with successively finer grades of wet-or-dry paper, starting with about 320 grade. Or, use an oil stone to polish off high spots.

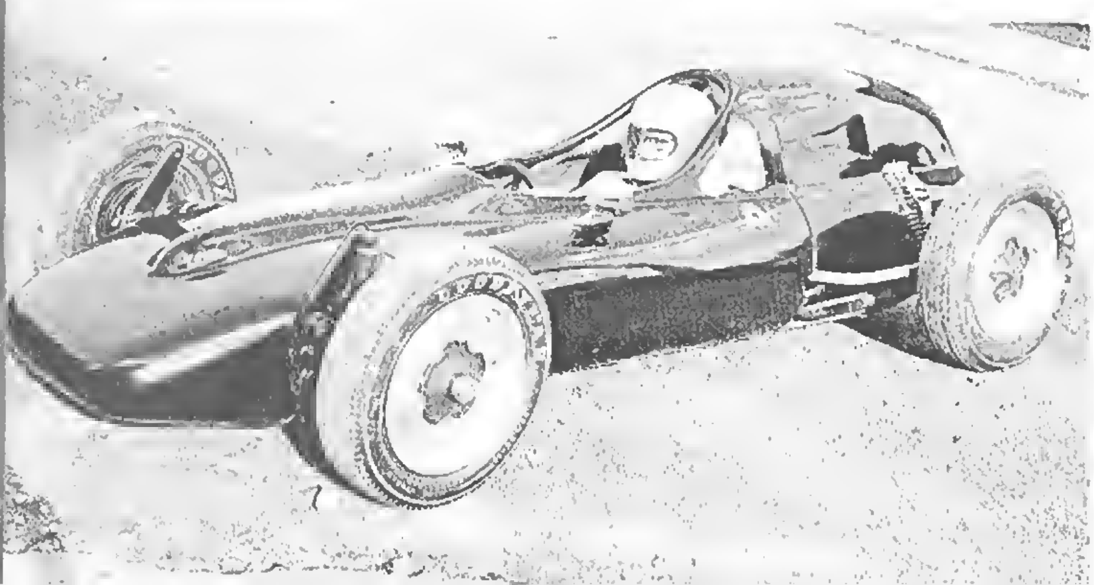
Install crank on its lubricated bearings in left half of crankcase. Install camshaft into lubricated bearings. Index cam gear into crank gear so valve-timing marks line up. Use the dial indicator to check that camshaft end play is between 0.002 and 0.004 with timing-gear backlash from 0.002 to 0.004 at one of the camgear teeth. VW uses selectively fitted cam gears to get the backlash exactly correct.

Install other half of crankcase but do not seal surfaces. Tighten two or three of the crankcase nuts. There is no reason to tighten all of them because the assembly will be taken apart at the conclusion of the degree checking. I always mark the mating gear (valley) with the matching tooth, using machinist's blue dye or nail polish and scribe marks so that the reassembly can be easily accomplished without errors. Install No. 1 cylinder, using spacer tubes, washers and nuts to hold the cylinder onto the case, being extremely careful not to break off any cylinder fins. Shortened piston pins work well as spacers. Install piston and connecting-rod assembly. Top and bottom rings should be used to hold the piston square in the bore, particularly if a dial indicator is used to find TDC. Attach the dial indicator so that its stem rests on top of the piston. Rotate the crankshaft slowly in a normal direction of rotation. When the dial indicator shows that the piston has reached its maximum travel, attach the degreed crankshaft pulley or attach a separate degree wheel to the stock pulley. Make an indicator tab from sheet metal or a piece of welding rod. Adjust the degree wheel and indicator to coincide with the TDC marking. Rotate the crank through an almost-complete revolution, stopping short of TDC when the dial indicator shows that the piston must still travel about 0.025" to reach TDC. Note the degree-wheel reading or make a mark on the crankshaft pulley. Continue rotating the crankshaft while the indicator passes through its maximum reading and backs down to 0.025" on the other side of TDC. Note reading. The ATDC reading should be the same as the BTDC one to show that you accurately located TDC. If not, start over again!

Another method positively locates TDC without using a dial indicator. It is so simple that it amazes me how few engine builders are aware of it. Bolt a strap across No. 1 cylinder. The strap should have a capscrew in its center, placed to extend into the cylinder. Set the degree wheel and indicator finger at TDC by guesstimate. Rotate the crank by hand until the piston stops against the screw. Note degree-wheel reading. Reverse rotation and turn the crank until piston again stops against the strap on the opposite side of BDC. Note the degree-wheel reading. Move the indicator to a point exactly between the two readings.

This same method can be used when the engine is assembled and in the car if

Autodynamics Formula Vee D-13 puts aerodynamics to work in the cleanest design yet produced for the class.



are is used. In this instance, the stop is made from a spark plug. Braze a piece of steel rod into an old plug base from which the insulator has been removed. The steel should extend about 1 inch from the threads. Remove all of the spark plugs from the engine. Install your special "plug" into No. 1 cylinder. Rotate the engine by turning the crank-pulley nut with a box wrench in one direction; with the fan belt in the other. Use extreme care so you do not damage a piston!

NOTE: The factory's timing notch on the crank pulley, when used in conjunction with the crankcase split line, is not a positive or accurate TDC location. Do not use it! There are no really reliable short-cuts for finding TDC or checking camshaft timing, so do not look for any. However, you can compare your accurate TDC location with the stock markings and scribe a correct line on the case to provide a true indication.

DEGREEING THE CAM

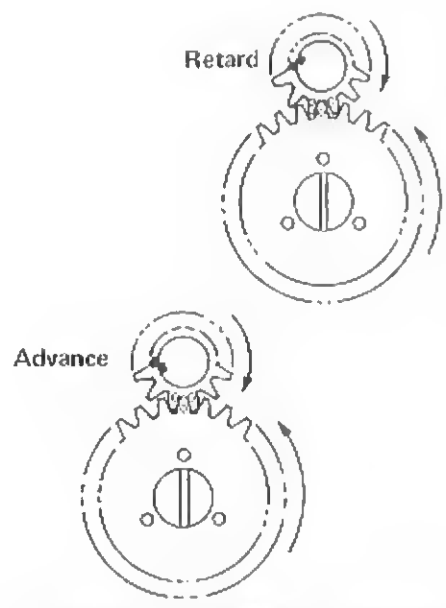
All cam grinders have established their own quality standards to ensure that you will receive an accurately ground camshaft. They cannot control the other parts in your engine. *Individual engines are different* and their differences can and do drastically affect valve timing. You can obtain maximum performance by making sure that the cam installed in your engine opens and closes the valves as intended by the cam grinder. And, with the VW there is a second valid reason which makes cam checking essential: consider the hours and hours and hours of wasted labor if subsequent removal and a complete teardown of the installed engine is required to correct valve timing! Finally, the manner in which the stock timing gears are indexed leaves something to be desired. It's no trouble to make an error in installation.

There is no doubt in my mind that you can install a stock or reground cam without checking. But, when you consider all of the tolerances working against you to cause less-than-perfect timing, why trust to luck? Some of the factors which affect timing include manufacturer's tolerances for the location of the keyways in the crank and camshafts and their respective gears—plus the cam grinder's lobe-location tolerances. If, for instance, the location tolerance for the crankshaft keyway and bolt holes in the timing gear and cam flange is $\pm 0.75^{\circ}$, you could get a tolerance "stack-up" of 4.5 crankshaft degrees total timing error with every item off by the maximum amount. It is assumed that you have carefully followed the instructions and have installed the degree wheel and accurately located TDC. With the lifter on the heel of the No. 1 cylinder intake cam lobe, adjust indicator stem parallel to lifter travel in all respects. Turn the crankcase sideways so that gravity will keep the lifter against the cam. Preload the indicator about 0.010. Rotate the crankshaft and observe the indicator, watching for the point of maximum lift. Mark this in pencil on the degree wheel as "IN" for intake. Rotate the crankshaft exactly one turn in the same direction until the pointer again aligns with your "IN" notation. This places the lifter in the mid-point of the cam lobe's clearance section. The cam has turned exactly 180° (half-turn). Without changing the indicator pre-load, set the dial-indicator face to zero. Rotate the crankshaft in the direction of running rotation and observe the dial indicator. When it shows that the lifter has raised an amount equivalent to the checking clearance, record the degree-wheel reading. This will be a certain number of degrees BTDC. If no checking clearance is specified or the cam tag has been lost, use 0.010" (close for most camshafts). Stock cams are checked with 0.040" clearance.

Continue to rotate the crankshaft in the same direction until the lifter has risen up in its bore and fallen back again as it followed the opening and closing flanks of the cam lobe. Watch again for the indicator to reach the checking clearance or the arbitrary figure of 0.010" just mentioned. Record the degree-wheel reading as the number of degrees between the pointer and BDC. Add 180° to your two readings to get duration of opening measured at the checking clearance.

Repeat the process several times to eliminate the possibility of errors. You may find that it is necessary to apply pressure against the lifter to hold it against the lobe, especially if you are making the check with the cylinders horizontal. Each repeat check must be started at the "IN" mark on the degree wheel and the indicator's needle and dial face must be at zero. Cam lobes and lifter bores must be scrupulously clean and lightly oiled so the lifter can move in and out of the bore without binding and of its own weight. With everything right, the indicator will reach zero and stay there before and after the mark on the degree wheel is reached.

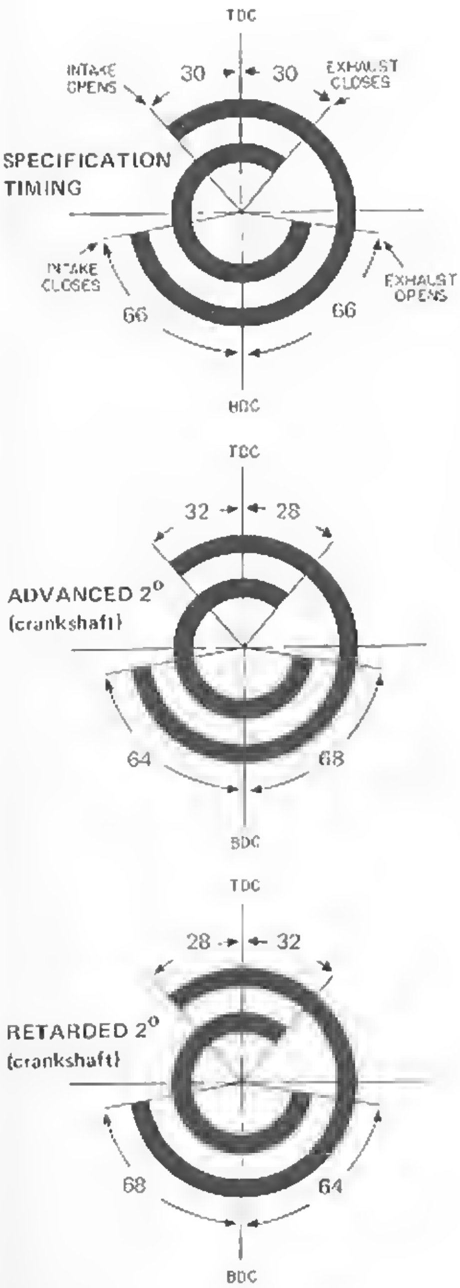
Transfer dial indicator to No. 1 exhaust and repeat the entire process, beginning with finding full lift, then turning 360 crank degrees and marking the wheel "EX". using this as your starting point, with the dial indicator preloaded about 0.010" and the indicator face set to zero. Exhaust-opening checking clearance will be reached at a point BDC. As with the intake, the number of degrees from the BDC mark on the degree wheel must be counted to get the opening point. Record this figure. Again, rotate the crank and observe the indicator as it indicates opening and then closing back down to the checking clearance. This will occur at a point ATDC, and the number of degrees from TDC must be recorded. Exhaust duration is calculated by adding 180° to the two readings recorded for exhaust timing. Again, repeat the process several times to eliminate the possibility of error.



Shows direction crank gear must be offset to advance or retard cam action.

Offset key at crank gear adjusts valve timing. If you adjust cam at the cam gear, adjust the cam—not the gear. Offset washers in precision counterbores at cam bolt holes can be used to adjust timing at the cam.

Overlap is easily determined by adding the intake-opening degrees Before Top Dead Center to the exhaust-closing degrees After Top Dead Center. The entire cam-checking process presented herein has been taken with slight changes from Racer Brown's camshaft catalog which contains other data on correcting errors, etc.



Comparison of normal specification timing with a cam advanced 2° (crankshaft) and with one which is retarded 2° (crankshaft). Racer Brown ST-22 cam used for this example.

VALVE TIMING CORRECTIONS

The previously outlined procedure—under ideal conditions—will show that timing points coincide precisely with those shown on the cam tag. But, due to factors already stated, variations can occur. A difference of one or two crankshaft degrees between actual installed timing and the cam-tag specifications should be considered the maximum-allowable error. A closer tolerance of ±1° (crankshaft) is even better.

If the timing check shows that actual timing is 'way off—10° or more—then the timing gears are probably misindexed by one or more teeth. Correct such a situation and rerun the timing checks. Racer comments that if an engine is run in this condition, or if the valve-timing check is made at the valves instead of at the lifters, it is a foregone conclusion that you will end up with an engineful of bent valves at the least. And, very probably, you'll also get bent pushrods, damaged rocker arms, and possibly even a bent or broken camshaft. These are just a few additional reasons why the timing check should be made at the lifters, as opposed to checking the timing at the valves, or not checking at all. Checking valve overlap with feeler gages at the valves by the so-called split-overlap method is not recommended under any circumstances because of the errors which can occur in rocker-arm geometry. *Feeler gages cannot be used for accurate checks!* Correcting a timing error requires rotating the camshaft in relation to the crankshaft, which can be confusing. It is important to take care to advance or retard the camshaft and *not the gear*! Remember that the gears remain in the same relative positions; it is the shafts which must be moved. This is true in all instances except where the cam and crank gears are misindexed, in which case the gear/shaft assembly is rotated. Assuming that the timing gears are held stationary, the drawing illustrates the direction the crankshaft must be moved to advance or retard cam action.

Three valve-event drawings compare specification timing with advanced timing (all events early) and with retarded timing (all events late). When an offset key is used, repeat the entire degree check to ensure that the correction has been made correctly, that is, corrected *the right amount* in *the right direction*. A movement of 0.0144 inch at the crankshaft nose (inside bore of crank gear) adjusts crank timing one degree. Correcting a 5° timing error would require an offset key to offset the crankshaft gear 5° x 0.0144 = 0.0720. Inexpensive offset keys can be used for making corrections, but all are labelled in *camshaft degrees*. Keys can be made by any machine shop. Rechecking timing after installing an offset key is essential!

Advancing or retarding the camshaft from the setting given by the cam grinder is idiotic unless you have access to a dyno and will actually run tests in the various advance/normal/retard settings that you are advocating. While this sort of jockeying has been known to cause an engine to run stronger at one end of the RPM range or the other—even most experts run their cams "straight up" at the recommended settings.

ROCKER ARM GEOMETRY

In addition to installing the camshaft in the correct relationship to the crankshaft, you must observe another important point of engine construction: the relation of the rocker adjusting screw (or rocker-arm-tip radius) to the valve-stem center. If this is correct with the centerline of the adjusting-screw tip coinciding with the valve-stem centerline at 50% lift—good things happen! Specification lift throughout the lift cycle of the cam is assured, side thrust of the valve stem against the guide bore is minimized to reduce wear and consequent oil consumption, friction is reduced, and higher RPM can be reached before valve float occurs. This is a point of construction which is often overlooked but it makes a vast difference in engine performance. Motorcycle race-engine constructors used and wrote about these things for decades; most auto-engine modifiers still refuse to realize that extra HP can be gained through careful attention to all details. Care produces more HP than a trunkful of "black-magic" tricks. Bike builders often had only one cylinder so they had to make it produce maximum HP. Always observe current developments in motorcycle engines and tuning procedures because you, too, are working with a tiny air-cooled engine.

Getting back to the tip/stem relationship, there are several things in the engine which can affect this relationship: head flycutting, cam, valve-seat location, valve-stem length, cylinder length, lifter dimension, rocker-arm differences, height of rocker stands, and pushrod lengths. Some of these things become immediately obvious as sources of problems when we are working on the engine—then we usually shrug our shoulders and forget about the problems and go right ahead with the engine assembly, never realizing that in so doing we have seriously short-changed our engine's breathing ability. Adjustments are possible through varying the height of the valve stem and/or the rocker-stands. Because of the production-tolerance stack-up which creates lift differences, the situation must be straightened out as follows: (1) tailor the individual valves so that their stem length is as nearly identical as possible, and (2) tailor the rocker-shaft stands by shimming or machining to get identical opening at full lift. This sounds complex and time-consuming. It is simple once the principles are understood, not really time-consuming, and you get free horsepower for your efforts!

Make all of the valve-stem heights (*not lengths*) identical within ±0.005" (the rocker-arm cover-gasket surface can be used as a reference point from which to measure heights). If any of the valves have to be shortened by grinding on the tips, reharden the ends by heating them cherry red and quenching in oil. Use a fairly large torch so the tip will get to cherry red quickly without the heat extending to the keeper groove. Hardening is only wanted on the tip. It is assumed that you have already seated the valves per directions in the section on cylinder heads. Reseating will change the stem heights, so do any seating prior to establishing the heights.

A hardened valve-stem cap or "thimble" P/N 113 109 621 can be very helpful in getting the valve-stem lengths correct. This item is stocked by VW dealers for quickly repairing worn valve-stem tips. Because the cap is hardened, it is logical to use these on the tips of valves which you have to shorten. It is safer to use these caps on the tips of all of your valves than to experiment with hardening the tips. Because the exhausts are usually shorter than the intakes, you may find that using these caps on the exhausts only will help to even the stem lengths.

How much should you shim the rocker stand away from the head or toward the head? If the centerline of the adjustment screw tip is just slightly above the valve centerline with the valve on the seat you are probably pretty close, but make sure as follows.

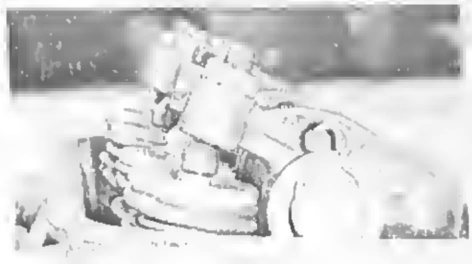
If you are in the process of assembling an engine, install a set of light springs in place of the stock valve springs, and put the adjusting screws in the center of their adjustment travel. You can make this part of the check before installing the cylinder heads, assuming that you have made all of the valve stem heights the same in relation to the gasket rail, as described in the cylinder head chapter.

Attach a dial indicator to the gasket rail of the head and place the indicator tip against a retainer. Install the rocker-arm assembly and depress the valve to 1/2 lift by actuating the rocker with your hand. The centerline of the adjustment screw tip should now coincide with the centerline of the valve stem. If the tip is above the valve centerline, you'll probably have to raise the rocker stand. Shim the stand and make the check again. When you have determined the correct shim-pack for each head, note what shims are required so that you will be able to assemble the engine without making the checks all over again.

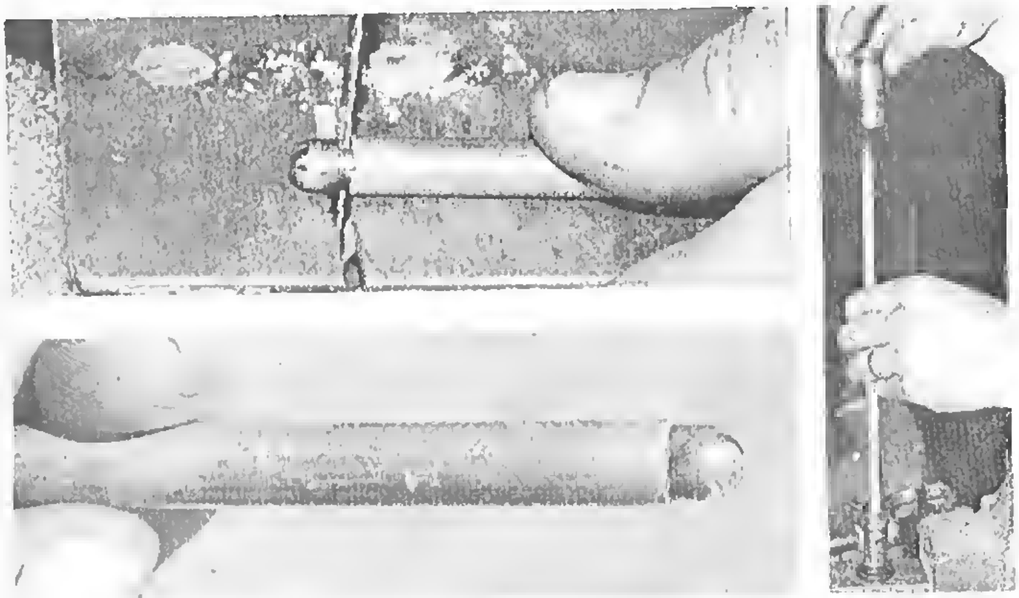
High-lift rocker arms with adjusting screws at the pushrod end of the rocker should be similarly checked to get the centerline of the radiused tip in line with the stem centerline at half-lift. Pushrod length can be established with an adjustable pushrod, also.

Correct pushrod length can be determined with the help of an adjustable pushrod during a trial assembly of the engine. Bolt the head in place and install the rocker assembly in position, using the shim-pack determined in the previous check. Make an adjustable pushrod by sawing apart a stock pushrod. Install a threaded rod or piece of bolt in one part, and drill out the other one so it slips over the threaded portion against an adjusting nut. Place the adjusment where you can reach it alongside of the cylinder with no pushrod tube in place. The pushrod can be installed by using your hand to operate the rocker so that the valve is depressed, thereby creating enough clearance to slip the two pieces of the pushrod together. Adjust the pushrod so that it fits, then remove it in the same way so that you can measure the pushrod with a set of 12-inch calipers. Or, if no large calipers are available, compare its length with one of the pushrods you plan to use so that you can see how much shorter or longer the pushrod will have to be.

When buying pushrods to modify, get a set which has not been assembled, or which is only assembled with the hardened tip in one end of each pushrod. It is tough to get the ends out of the pushrods, especially chrome-moly steel pushrods (recommended), because they are installed with a tight drive fit.



Swivel-foot adjusting screws are another Gene Berg trick widely accepted by VW builders tired of replacing chewed-up valve stems. A set of these will demolish a $20 bill, but they're worth every penny. Higher-priced Porsche 911 screws are similar but they require shortening and reslotting to give clearance for the rocker cover.



Three photos illustrate pushrod shortening. It's difficult to get the pushrod end out of aluminum or chrome-moly pushrods, so bandsaw away the amount you want to shorten the pushrod support. Support pushrod in one tappet and use a hammer on another to drive the end into the tube. Finished job is neat.

Stock or replacement aluminum pushrods often flex when RPM's get higher than 4,500, causing wear such as that shown here. Most VW hotrodders prefer chrome-moly pushrods because of their resistance to bending under load.

As you can see from the foregoing discussion, you should ignore the simplistic statement, "When heads are flycut, shorten the pushrods or shim the rockers by the same amount." This is just one more of the easy ways out that will eventually leave you up a creek without a paddle.

ROCKER ARMS

There have been two types of forged-steel rocker arms used in VW engines: 1.1:1 ratio in 1300/1500/1600 engines (including the early 1500's) and 1:1 ratio in the 1200's. As of 1969, accessory maker EMPI began selling forged-steel 1.4:1 high-lift rocker arms modelled after high lifts which were first made from Porsche rockers by Gene Berg for his "Little but quick" dragster engine. And, in 1970, Air World started producing 1.4:1 investment-cast steel rockers with needle-bearing trunnions. High-lift rocker arms made from magnesium have been made for several years, but the quality and reliability have been marginal. All of these require shorter pushrods.

Late in 1970, Gene Berg added 1.3:1 forged-steel high-lift rocker arms to his catalog of VW goodies. These are adapted from the VW 411 Series engine and are offered in both plain-and needle-bearing styles, complete with modified stands and new hardened shafts. These do not require using a different pushrod in most installations.

Before you rush to spend your money for a set of these high-lift rockers, remember that higher-than-stock lifts are not really very effective unless the heads have been modified to flow more air. Look at the air-flow tables in the cylinder head section before you make up your mind. If you install high-lift rockers, remember that the valve springs must be checked at peak lift to make sure that coil binding is not occurring. And, the distance between the underside of the spring retainer and the top of the guide must be adequate to allow the higher lift to be used without interference. Whether you use stock or high-lift rockers with plain-bearings (not needles), you'll be wise to heed the following admonition. *Polish the shaft, polish the shaft, polish the shaft.* Get the idea? Don't fail to do it because the rocker arms operate under a lot of heat and friction, wearing away at the shaft, which is only marginally lubricated at best—so failures are common.

Don't reinstall a rocker-arm assembly until you have disassembled it and checked the shaft and rocker-arm bores for wear, galling and scuffing. Check the side thrust surfaces of the rockers and stands for scoring or roughness. If you find one that appears to be wearing or scuffing, file two half-round reliefs 1/16-inch wide at the top and bottom of that edge of the rocker arm. This increases the oil flow at this point to reduce wear. Also check the adjusting screws and the ball sockets in the rockers for wear.

If any part is severely worn, discard that part and install a new one. Replace the wavy washers at the right side of each rocker which is on the right side of a rocker stand. There should be three solid washers at the right side of these rockers: No. 1 and 4 exhaust; No. 2 and 3 intake. Solid washers at these points keep the adjusting screws aligned with the valve stem at high RPM's. Note that the slotted rocker stands are installed with the slot up and the chamfered edge out. Gene Berg uses three washers at the outside of all eight rockers instead of just the four which get the worst side loading. He uses two stock flat washers, one on each side of a VSI-300 0.060-inch valve-spring shim.

When you have an engine that has good high-RPM capabilities, there is a very good chance that the snap-clips which are used on the rocker shaft will come adrift. These never cooperate by coming off in your driveway, so it is best to machine a piece of tubing to serve as a spacer between the two intake rocker arms, using a flat washer at each end between the spacer and the rocker. The

exhaust clips are more of a problem. Here you should machine a groove around the shafts at each end and use a high-quality snap ring (circlip) to hold the washers in place.

At least two styles of rocker arm shaft supports (stands) have been used. The square version introduced on the 1965 engines has an offset bore for its shaft, so it is important that the stands be installed the same way or you could create problems. It is possible to reverse the stands so that the side which ordinarily goes toward the rocker cover is placed against the head instead. In the ordinary position, the shaft bottom edge is 0.200 inch from the mounting surface. Reversing the block places the shaft 0.110 inch from the mounting surface. However, if the block is reversed, it is possible for the underside of the rockers to rub against the head. Reversing the blocks will sometimes allow using stock-length pushrods when a reground camshaft is installed. The early rounded-edge style blocks mount the shaft 0.165 inch and 0.145 inch from the mounting surface, depending on how they are installed, so here's another possibility for getting the rocker-arm geometry right on. As the stands are a mere 55 cents, changing the stands around could be the way to get your heads set up perfectly.

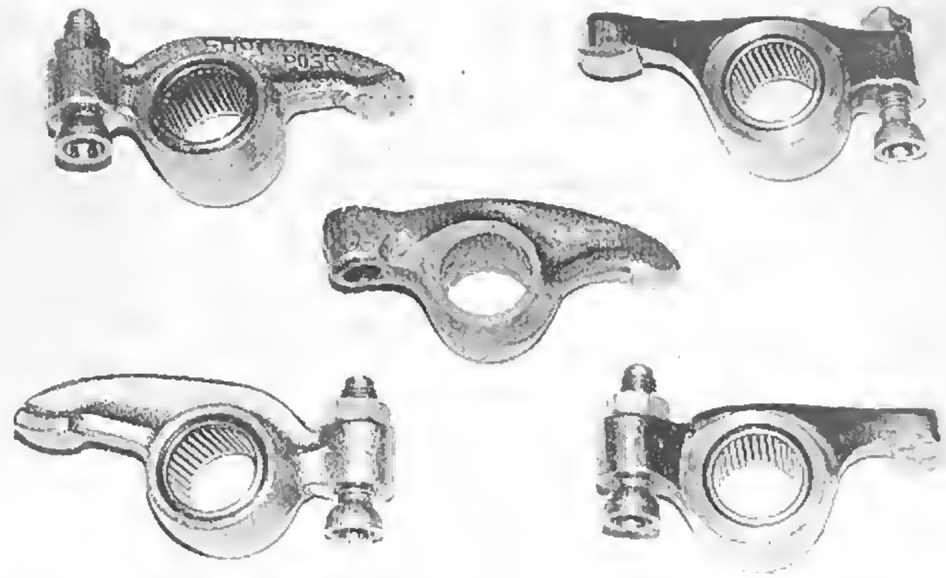
VALVE SPRINGS

There have been three types of valve springs offered in the VW engine, with the latest 1600 springs often being supplied by dealers, even though a lighter spring exists for use in the 40 HP. The first of the three springs is easily identified because it is non-progressive. The second and third springs are progressive. The latest and strongest spring is identified with a purple stripe.

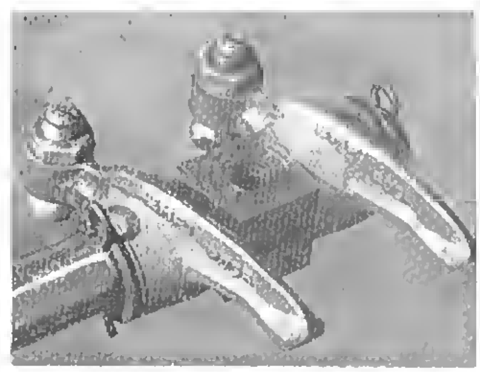
Always use the lowest valve-spring pressures which will cause the valve train to follow the cam profile to the desired RPM with some safety factor for over-revving. Excessive spring pressures cost you HP and hasten wear of the entire valve train.

Hal Kleeves says, "Uniform spring pressures are more important than total pressures. 110 to 115 pounds is adequate with stock cams, even though the factory seat-pressure specification is 126 pounds." Don Baker points out, "When setting up stock engines for the drags or Formula Vee, it is extremely important not to try to make the engine 'bullet-proof' because you have to add too much weight and friction in the process. For instance, it is better to use stock springs of consistent tension without shims because heavier springs slow down the valve train, cause excessive drag of the lifters against the cam and cause excessive friction at the rocker-arm shaft, too."

When the valve is at full lift you should be able to pass a 0.010-inch feeler gage through the spring coils. Inner springs are checked alone, with the measurements made to the outer-spring seat of the retainer. If the feeler will not pass between the coils, the installed height must be adjusted to provide clearance between the coils at full lift. The man who assembles springs on valves without checking height, clearance between coils and between the retainer and guide end at the full-open position, is asking for a damaged engine. You cannot assume that "everything will average out"—because it usually won't!

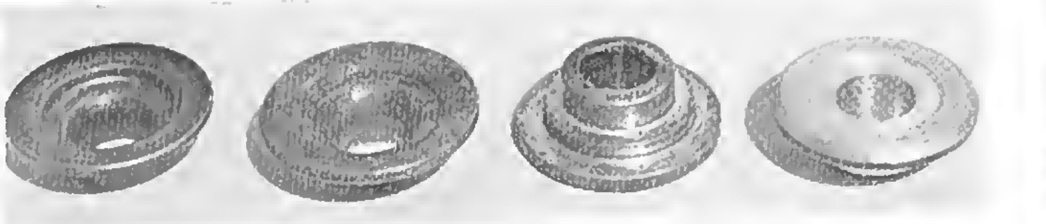


EMPI high-lift 1.4 rockers at left have been fitted with needle-bearing trunnions for high-rev application. Center rocker is Berg's original 1.4 model made from Porsche. At right: Air World's needle-bearing-equipped 1.4's.



1.4:1 high-lift rocker arms made of forged steel are available from EMPI. Fit onto stock VW's without modification to give racing-cam effect. When used with a cam, valve retainer to top of guide clearance must be checked.

Checking required shim dimensions to obtain correct installed valve spring height. Welding rod ground to correct height simplifies procedure because shims can be stacked between rod and underside of retainer to get correct pack. Valve-guide bosses have been machined for use with inner springs or outer springs with damper spring.



Four valve-spring retainers. Left to right: early stock, late stock (note radius construction and heavier metal), aluminum retainer which pulled through because taper did not fit that on the keepers, and a new aluminum retainer.

VALVE SPRING RETAINERS

Aluminum valve spring retainers are in widespread use for VW high-performance engines. These typically weigh about 8 grams, while the stock late-model steel retainers tip the scales at 14 grams. For most low-lift camshafts using a single spring or spring with built in damper, use the stock steel retainer because it will not wear from the damper spring. Aluminum retainers wear, getting flakes of aluminum into the oil—which can go through the pump and into the main, rod and cam bearings to cause failures. Even worse, failures of the retainers themselves have been known to occur with high lifts and high spring pressures, especially where the valve-keeper angle did not mate perfectly with the taper in the retainer.

You do not want the aluminum retainers in a VW engine unless you have installed a full-flow oil filter to catch the debris which they can create. For most high-lift cams and double springs or double springs with a damper spring, use the late stock retainers. If you can't find any and have to use an aluminum retainer, be sure that the springs fit onto the retainer very snugly and that the angle of the keepers mates with the tapered bore of the retainer. You can check this fit with bluing. If the keepers don't mate over the entire surface of the retainer bore, don't use 'em . . . even if you have to make your own.

If you are building a competition engine, adjust the rocker arm positioning on the shaft with spacers or stand modifications so that the adjustment screw tips center on the valve stems (from right to left).

ROCKER ARM COVERS

Rocker arm covers might not seem like a part of the valve mechanism, but they can interfere with valve action. You can see that this is an area which needs your attention. When using a high-lift camshaft or high-lift rocker arms or the swivel-foot 911S rocker-arm adjusting screws (longer than stock adjusting screws), bolting the valve covers on may open a valve. Don't think for a minute that this kind of problem hasn't created its share of frustrated VW mechanics. If you spread machinists' blue dye on the inside of the stock covers before installing them, you can check whether the rockers are hitting by looking for bright spots when you pull the covers off after turning the engine through several revolutions.

If there are places where there is contact with the covers, place the cover over a socket and dimple it slightly with a ball-peen hammer. With solid aluminum covers such as those made by Eelco or Segal, you'll have to resort to a rotary file to make clearance. These can cause the valves to hold open just because the covers do not bend when they are compressed on the gasket by tightening the two hold-down nuts. EMPI's and Kal Kustom's have adequate clearance built in.

OVERSIZE VALVES

I've mentioned installing bigger valves in the cylinder head section—is it worth the time and money? It most certainly is, especially when you are installing a special camshaft. Larger valves help you get your "money's worth" in performance. The combination of big valves and a special camshaft should add 15 to 30 HP to any VW engine if properly installed and tuned. That kind of horsepower cannot be overlooked by any serious competitor.

The gain in power afforded by larger valves is attributable to the added mixture-flow area (circumference X lift) when the

Joe Vittone, EMPI's President, shows us how U-shaped gasket fits onto his rocker-arm covers. Seals at bolt holes are similarly ingenious. These are the only covers which won't leak, regardless of how many times you take them off. Square shape accommodates highest-lift cams without interference.

valve is opened. With a larger-than-stock valve, the area is greater at every portion of the lift curve. Bigger exhaust valves are equally important in making these engines breathe, especially at high RPM. Regardless of the type of cam you choose, install larger valves in your dual-port heads if your budget permits.

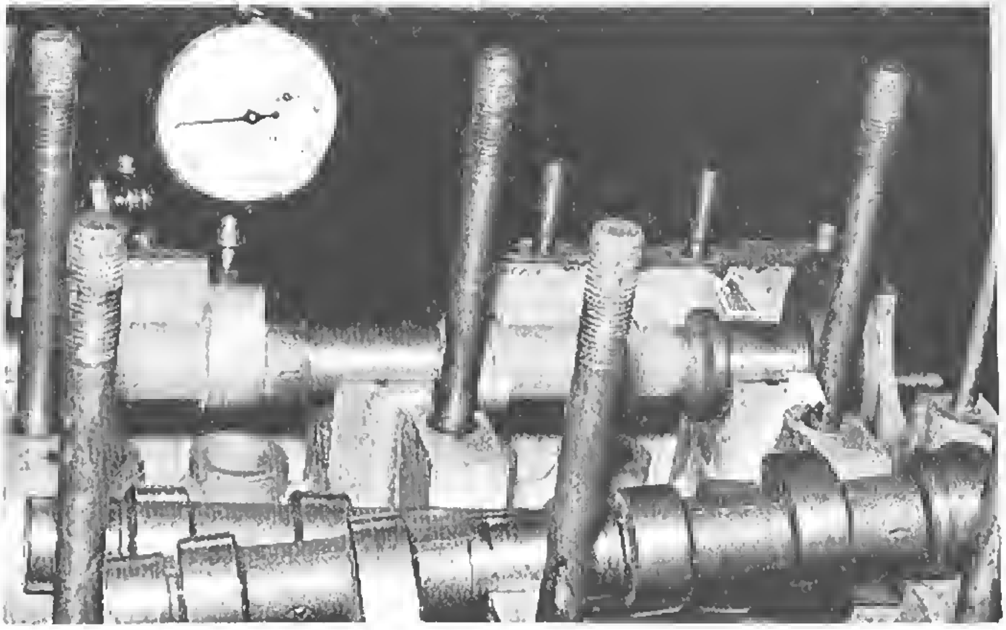
NOTCHING PISTONS FOR VALVE CLEARANCE

It's essential that you measure the clearance between the piston and cylinder head at the flat-deck portion and between the pistons and valves. Each head is prepared complete with valve, springs and retainers. Light springs can be used for this assembly. A strip of clay 1/2-inch wide X 1/8-inch thick is placed across the piston to coincide with a line through the four valve guides. Another strip is placed at 90° to the first one to coincide with the deck area of the head. Clay can be attached to the pistons with cellophane tape. Torque the heads and add the pushrods and rocker arms. Adjust rockers to provide no clearance by watching lifters for opposing cylinder. When opposing

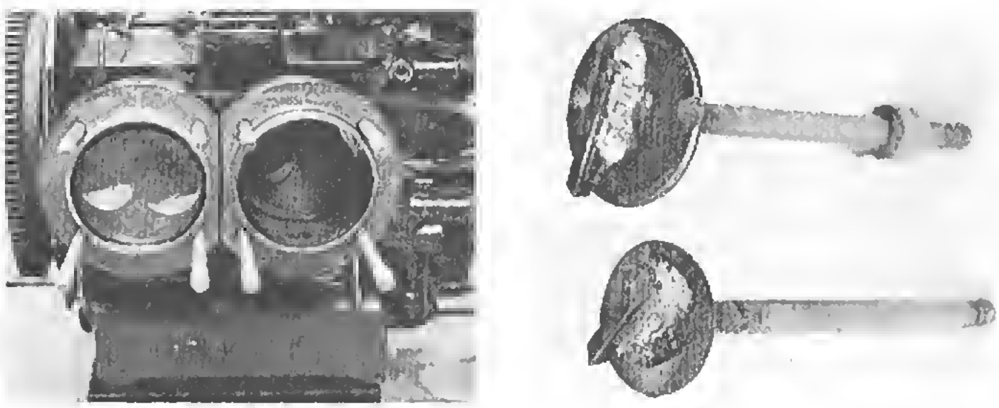
cylinder intake valve is full open, set intake clearance on cylinder being adjusted. When opposing exhaust is full open, set exhaust clearance. Turn engine through two complete revolutions after setting all of the valves at no clearance. Feel carefully as you do this, and if you encounter any resistance, STOP. Determine the cause. Use a small penlight to peer into the plug holes to see whether a piston is hitting the head or a valve is hitting a piston. If no interference is encountered, remove the heads.

An X-Acto knife or razor blade can be used to cut carefully through the thin portions of the compressed clay on the pistons. A 6-inch machinist's scale can be used to measure the clearance for the valves and deck (thinnest points tell you what clearance exists). If the deck clearance is less than the 0.040" recommended minimum (0.060 for roller cranks), refer to the details on setting deck clearance in the blueprinting chapter. Should there be an imprint of one or both valves at any piston, cut through the clay at those points to see what clearance exists. If the thinnest point is 0.090 inch or greater, there is no problem. If it is less than that, the clearance must be increased to at least that amount. Clearance can be increased only on the "offending" piston if the other pistons are rebalanced to that weight, or you can cut the same amount of clearance on each piston to keep the weights equal.

Clearance is added by using a valve 1/8-inch larger in diameter with a face having eight or more saw or file cuts across it. Or, braze a cutting tool onto a valve to cut a diameter 1/8-inch larger than the valves you will be using in the head. Install the cutter-type valve in the guide of the cylinder requiring more clearance, and bolt the head on with four nuts. Just bolt it on firmly, there's no need to torque it down. Bring that piston to TDC and drop the valve onto the head. Using a scale, measure from the end of the guide and mark the dimension for the clearance to be added by putting a piece of masking tape on the valve at that point. Or, position a set-screwed collar on the valve at the point which will provide the desired clearance. If the clay measured 0.030" at the thinnest point, the added clearance required is 0.060 inch.



Dial indicator can be used to measure lift at the cam. Multiply measurement by rocker-arm ratio, then subtract operating clearance to get lift at the valve. Arrows indicate thrust surfaces which must be smooth before cam is installed.



Tool bits brazed to valve heads make cutters for providing valve clearance in head of piston, as shown in these photos of Doug Gordon's Underdog engine. Collar with set screw is used to stop cutter at depth required for clearance. "Cutters" can be driven by electric hand drill. Note chopped flywheel. Photo by Waar.

Chuck the valve stem in a drill which turns slowly, preferably a variable-speed kind. Keep oil squirting into the guide and squirt kerosene onto the cutter through the spark-plug hole. Start the drill and keep pressing the cutter against the piston until the collar or tape comes even with the end of the guide. Repeat for other cylinders with valves which require additional clearance. Be sure to lock the crankshaft against turning or the piston may move away from the cutter, giving you a false indication that you have added enough clearance. The cutter correctly positions the "notch" in the piston for the added clearance, but you will have to finish the piston head by hand scraping and polishing to eliminate sharp edges. Measurement and replacement of the tape and collar must be done for each valve because guide heights vary considerably.

Blueprinting

build your engine like the designer intended

You've heard this term lots of times. What is it and what does it mean to you and to your VW engine? How can you apply it to make your VW run faster, farther and cooler? Blueprinting is the tedious process of making your engine come as close as possible to the ideal engine that the designers intended—as opposed to the more usual process of assembling random parts with some specifications exact and others at the scary edge of being too tight or too loose because of tolerance stack-up.

And, it includes making sure that all of the items which need to be either parallel and/or perpendicular to each other are exactly that. For instance, the crankshaft and camshaft should be parallel with each other and with the case split. Would you believe—they usually are! This is due to the rigid machinery and precise tooling used by the factory. Seating surfaces for the cylinders should be parallel with the case split and the same distance from the crankshaft centerline. They won't often meet these requirements, except on some new cases, because the heating and cooling cycles which the engine lives with cause the cylinders to sink into their seats—often at an angle.

Bearing bores in the case must be round and should provide the correct bearing crush. Cylinder lengths should be equal, compression heights of the pistons should be the same, and the end-to-end distances of the connecting rods should be identical. Connecting rod big-end dimensions must provide the correct crush for the bearings and the correct side clearance in the crank throw. And, the pistons and rods must be assembled in sets and aligned so that the pistons will travel straight in the cylinders without cocking or twisting. The crankshaft throws should provide identical strokes for each of the pistons and at the correct number of degrees of rotation in relation to each other.

Cylinder heads should be flycut to equal depths. I am not calling off all of the things which must be done to make the engine right—just naming a few so that you get the idea of the enormity of the task if the job is to be done right. Other areas of blueprinting include installing the cam as it was intended, which means you have to degree it to check what is necessary to make it so. And, the entire engine must be assembled, usually several times, to get the valve-train geometry correct, pushrod lengths set, valve-stem heights equal, deck height as you'd like it, and adequate clearance between the valves and pistons at all phases of the operating cycle.

Many of the items relating to blueprinting are scattered throughout the book: in the camshaft chapter, with the piston details, in the crankshaft section, in the balancing write up, and there are even references in the assembly chapter. This kind of work and attention to detail helps your engine to stay together because everything works better when you have removed the variables induced by production tolerances or wear. You'll have less problems with cylinder-to-head sealing, of course, and there will be more HP available at the crankshaft. Why? Pistons will be working in a straight line in cylinders which are straight, so the power that was being lost as heat through unnecessary friction can be applied to the crank.

The foundation of a completely blueprinted engine is the crankcase, and that portion of the blueprinting task is discussed in this chapter. Some of the information which has been whispered about how bad VW cases are would make a Wolfsburg quality-control man's eyes water. But, while they are not so bad as some would have you believe, measurements to make sure that the case is as good as you'd like are essential—even with a brand-new case.

First examine the case sealing surfaces. "If your case is badly fretted at the sealing surface, especially around the No. 2 main, throw it out," says Rimco's Jack Riddell. "Corrective work is so costly that a new case is the thinking-man's smart solution. You can only take 0.004" off of the left side if you want the distributor gears to mesh correctly; not enough to clean up a badly fretted case. The cam bore is pulled so badly out of shape by the No. 2 main when it's pounded out of round, that it has to be remachined after boring the mains.

When an engine has been run so hard that the case mating surfaces (bottom arrows) are fretted or galled from rubbing against each other—and the bearing numbers have been pounded into the bearing bores (upper arrows)—measure everything very carefully for wear and roundness. Chances are good that you'll have to buy a new case to replace one that's had such a hard life.

After adding up all of the costs to machine the other items after planing off mass, the startling total involved has caused us to recommend that customers scrap such cases."

Rimco, in case you were wondering, is a tool-and-die shop whose owners Frank and Jack Riddell decided that VW cases needed to be machined correctly. They built production-line-type machines to accomplish the required tasks with better-than-usual accuracy. Where required, as in line boring mains, a massive jig borer is used with huge fixtures that ensure that the new bore will be parallel with the case centerline.

Back to your case . . . whether it is new or used, stone off the split surfaces lightly to make sure that there are no high spots. Bolt the case together to the specified torque. Leave the cylinder studs installed. Use a bore gage, snap gage or an inside micrometer (in conjunction with an outside mike which you have calibrated) to check whether the main bearing bores are round and within specifications. If the bores have worn to some shape other than round, line bore the case for oversize main-bearing shells . . . after you've done more checking. Take the case apart and determine whether the main bearing bores are positioned parallel to the case split. They usually are, incidentally. There's a common misconception that a case needs a corrective line-boring job if the bearings happen to be deeper in one case half than the other. This is some more of that hokey I was telling you about. If the crank is parallel with the split and the bearing bores are round, there's no need for such work. If you measure your case's main-bearing bores and find that the crank is 0.0025" farther in the left side than in the right—but parallel with the split and bearing bores offset by the same amount—don't worry about it because your case is like thousands of others. You should remember which way the bores are offset and how far so that you can take this into consideration when machining the cylinder seating surfaces.

The accompanying photos and captions show how to make these measurements.

Most line-boring equipment has little or no capability to correct a hole which is not parallel with the case split. This is because such equipment, including reamers designed for the task, aligns on the existing bore to provide new holes in a straight line *with the old ones*. So, if your crank isn't parallel with the case centerline, correction will be accomplished automatically when Rimco bores your case.

If the crank is parallel with the case split, then a local machine shop can indicate the cylinder base surfaces and get them machined off so that they are parallel with the split and equidistant to the crank centerline (which may not be in the same plane with the case centerline, as previously mentioned). And, any capable machinist with a good milling machine can open up the cylinder spigots in the case to install larger cylinders. The same is true for flycutting heads or trimming cylinders to length. Should your case be an older 36 HP or 40 HP unit, Rimco can install insert-type cam bearings to ensure that you'll have good oil pressure after your rebuild. There's no need to bore 1300/1500/1600 cases for oversize cam bearings because these tend to stay round.

1

If you don't have the precision tools required for this checking and have to get the case bored for larger cylinders anyway, clean off the grime, disassemble the engine and reassemble the case, leaving the studs installed because you don't want to take them out and run the risk of destroying threads as the studs come out or go back in. Frank Riddell says that he's seen would-be VW mechanics drop a stud on the floor, then pick it up and install it without even looking at the threads to see whether they have been damaged. The result is nearly always another thread destroyed in the case. Rimco can check the case for you to determine whether oversize main bearings are needed. They'll only do the work if it is needed. Their massive jig borer works from the case centerline to give main bores which are parallel with the case split and in an absolute straight line with one another. This setup also corrects any non-parallelism of the bores with the split, which is rare. They'll also machine the cylinder base seating surfaces so that they are parallel with the case. This is done as part of boring the spigots for big cylinders. And, they can install case-saver inserts at any stud location, regardless of cylinder size.

Rimco charges \$20 for boring case and heads for larger cylinders, \$29 for line boring mains (including the oversize inserts), and \$55 for line boring 36 HP and 40 HP main bearings and installing insert-type cam bearings (including inserts). For another \$15, off-roaders can have the thin National 340400 seal installed and their pulley hubs turned down.

2

If you live in the eastern half of the country, consider using Race/Chek to bore your case for bigger cylinders, and set cylinder base surfaces dead true with the case split. Price is about $35, plus another $30 to set all of your cylinders right on the same length. Hal Klieves of Race/Chek says that it is not unusual for cylinder base surfaces to be out of parallel as much as 0.010 inch, usually due to wear.

CASE SPECIFICATIONS

Main bearings 1, 2, 3	65 mm/2.5591 - 2.5598"	wear limit - 2.560"
Main bearing 4	50 mm/1.9685 - 1.9695"	wear limit - 1.970"

Main bearings shall not be more than 0.001 inch out of round.

Cam bores for inserts	27.5 mm/1.0827 - 1.0835"

Dimensions shown provide correct "crush" to main- and cam-bearing shells.

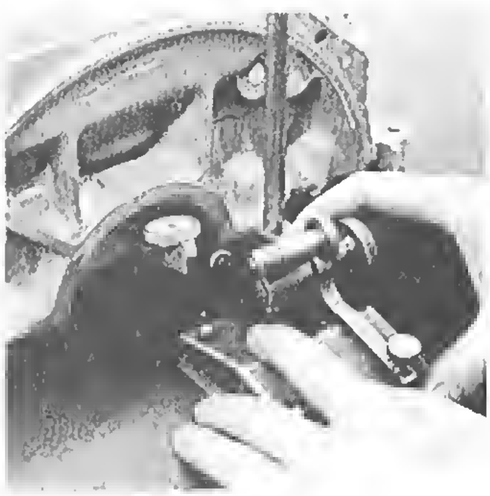
3

Tool-and-die maker Dean Lyon blueprints VW's and Porsche cases for a few of his acquaintances when time permits. In this photo sequence he shows us what's involved in making measurements to see what needs to be done to the crankcase to make it right. Photos 1 and 2 show two ways of measuring the height of cylinder bases from the crankshaft center line. Here a surface plate is used with a height indicator to check the bases around their circumference. Depth-gage measurement to surface block only tells you an average measurement of how far two points on the base are from the centerline, can't spot tilted base—a common ailment.

4

Photos 3 and 4 illustrate stoning-off raised edges around stud and dowel holes. Light-color rings (arrows) on surface show where raised portion has been stoned off to flatten surface; proof-positive that removing the studs moves metal into places where it could interfere with precise measurements.

5



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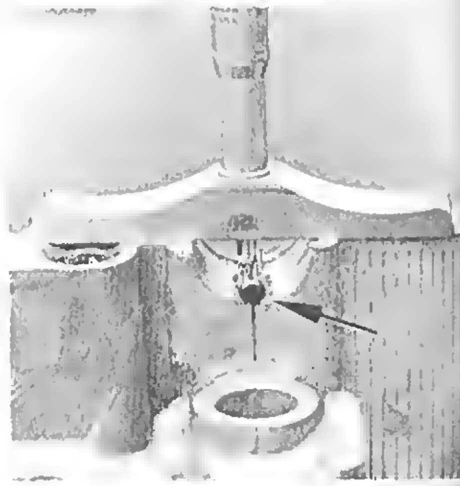


7

5, 6 and 7 show how to measure the bearing bores for centering in the case. Arrows point to dowels which are used between the case and tip of depth mike to ensure accurate readings. Remember to add diameter of dowel to depth reading. Height gage can be used to check bores for centering by merely moving the gage from one half of the case to the other with both on a surface plate. This method is preferred by precision machinists because there's no need for arithmetic to get an immediate answer.

8 and 9 show use of inside mike to check bores of torqued-together case. Center bearing bores can be reached through cylinder openings if your hand is small enough. Snap gages are preferred for these measurements, but inside mike can be used if you mike it with an outside mike that's been calibrated.

8

9

10

10 illustrates measuring depth of flycut from machined fin surface to determine whether both chambers have the same depth. Note that blade-type depth mike is used here at the center of the head. Lyon points out that some mills, even very good ones, have a tendency to "fall off" at the ends—or droop—when traversing a distance equal to the length of a VW head. The most meaningful measurements can be made from the center of the head. The "droopy" problem is minimized by centering the head on the mill table.

DECK CLEARANCES

Dean Lyon points out that it is literally hopeless to try to get deck clearances "right on" unless you check the case to make sure that it has been machined with half of the crankshaft bores in each half. This can be done with a surface plate and an internal micrometer to measure between the plate and the inside of the bore of the No. 1 main bearing (by the flywheel). Once you have made sure that the case halves are not machined off-center, the surface plate should be used with a dial indicator to check whether the cylinder mounting surfaces of the case are equal and true for both case halves. If not, the condition should be corrected so that the dimension from the case centerline to the cylinder mounting surfaces is equal for each half . . . and so that the mounting surfaces are flat and parallel with the case centerline.

Lyon also suggest that flycutting of the cylinder heads be preceded by taking a skim cut off of the rocker-gasket rail before attempting to do any work on the cylinder spigots or seating surface for the cylinders. The rocker gasket surface may take from 0.005-inch to 0.020-inch to "clean up"—so it is important to get this surface straight and true before proceeding. Then the head can be flopped over so that the cylinder spigots can be cut, but only if the mill head has been "trammed" and found to be within 0.0005-inch Total Indicated Runout (T.I.R.) over an 8-inch travel. If the mill head is not true within this specification, then the sealing surfaces will be cocked the same way for each cylinder and the head will only contact the two cylinder's sealing surfaces correctly at two points—rather than around the entire sealing surface.

Ray Litz suggests that 0.001" T.I.R. will be adequate, even for a racing engine.

Reducing deck clearance - Eliminating the base gasket does not reduce the deck clearance enough to get the 0.040-inch clearance which is wanted for best performance. Take the thinking-man's approach so that you will not have to do any more machining than is absolutely necessary. First, do all of the connecting rods have the same length? Measure them to find out what the center-to-center distances are and record them. Next, do all of the pistons have the same compression distance (height)? That's the dimension between the center of the piston pin and the piston crown. Measure them and record the measurements. Be sure to mark the rods and the pistons so that you can identify what measured out to be what . . . otherwise, it'll be start-all-over-again time. If rods differ more than 0.005-inch in length, they should be rebushed and bored for closer end-to-end tolerance.

If the rods have different lengths and the pistons have different compression heights, match the short rods with the longest compression heights and vice versa to help even things out before you start to assemble the parts. After installing the rods on the crank and the pistons and pins onto the rods, install the cylinders. Hold the cylinders in place with flat washers which are pushed down by short lengths of tubes held under the head nuts. Measure the deck clearance at each piston. Hold a straight edge across the end of the cylinder and measure the clearance with feeler gages. Or, use a depth micrometer or a caliper.

One cylinder will be closest to the required deck clearance. Lathe cut its base to give the exact deck clearance. Then lathe cut the other three cylinders by cutting the same amount from their bases because you want to end up with all of the cylinders having the same length. This avoids sealing problems at the head joint. Cylinder bases are cut by chucking the head end of the cylinder and supporting the case end in the lathe's tail-stock center. Final "tuning" of deck clearance is accomplished by lathe cutting the piston crowns of the remaining cylinders. But, don't take more than 0.015-inch off of the head of any piston. If you find that a deeper cut is required, then you may have pistons which are out of tolerance—or connecting rod lengths may need to be machined to get them closer.

Engine assembly

. . . and disassembly . . . take time, care & patience

Putting a VW engine together in a winning combination is TEDIOUS! No other word describes it. If you are in a hurry, bury or burn this book because it will have been of no value to you. It's amazing to me how a man will put hundreds of dollars into cylinder heads, cam, carburetors, pistons and cylinders—and so forth—and then insist on hurrying through the marriage of these expensive parts. The most unfortunate ending to this story is that these same "men" are quick to blame the manufacturers for turning out such "lousy" merchandise. The old adage that haste makes waste can be no better applied than to the job of assembling a high-performance engine. One of the best, shortest and most meaningful comments on assembling the VW engine comes from Hal Klieves of Race/Chek in Pompano Beach, Florida.

> *"The best procedure for building any engine is patience, care and constant rechecking."*

Engrave that statement on your headbone. Rechecking is the one outstanding trademark of the professional racing-engine builder. The average mechanic is quite content to bolt an engine together *once,* but his patience turns to anger if he ever has to take parts off or go back and do the job over again.

Extra assembly—even three or four times if that's what it takes—measuring disassembly, modifying, reassembly, rechecking and so on can be satisfying or frustrating, depending on your temperament. If you are easily frustrated and become angry when setbacks thwart your progress, forget about ever laying a wrench on the VW engine. Pay the cost and have the work done by an expert because engines jammed together hurriedly will never win races—or reliability contests, either.

This section is probably misnamed because it also covers a great deal of information on preparing for the job at hand so that the frustrations will be reduced during the actual work. Some additional details are provided on torque measurements and clearances for handy reference. Careful attention to details ahead of the time when you pull the engine can definitely shorten the amount of time required to get the engine back together and into the automobile again. Such items are important whether the engine is used for competition—where it is important to get ready for the next race—or for transportation where the car should not be kept out of service for long periods.

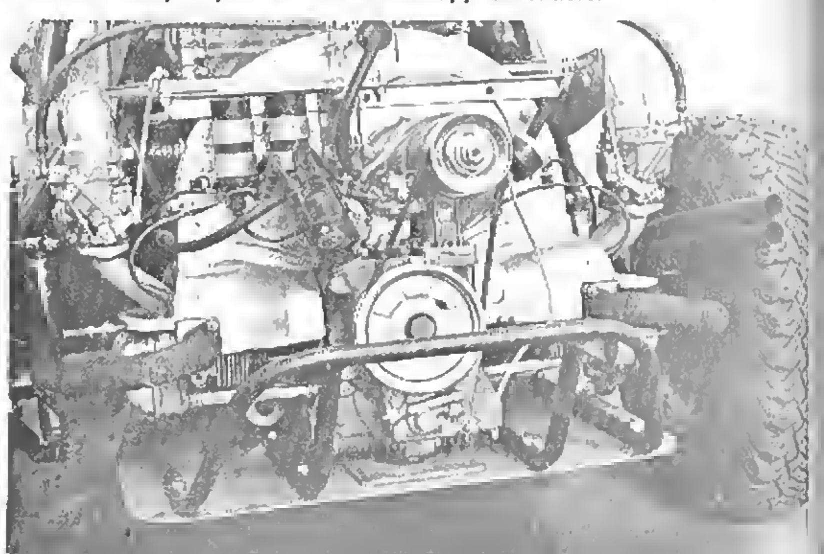
Many enthusiasts have difficulty getting all of the needed parts together at the right time so that the work can proceed without delays when it is started. You should order all of the components which will take time for delivery, then wait for these to arrive—and do any of the work which is then required on those parts—before even taking the engine out of the chassis. Oil coolers, hoses, pistons, rings, bearings, camshaft, special crankshafts, valve springs, retainers, and other parts often take some time to arrive after you've purchased them. Note that stock VW parts of the types required for racing engine construction may not be in the local dealer's parts bin.

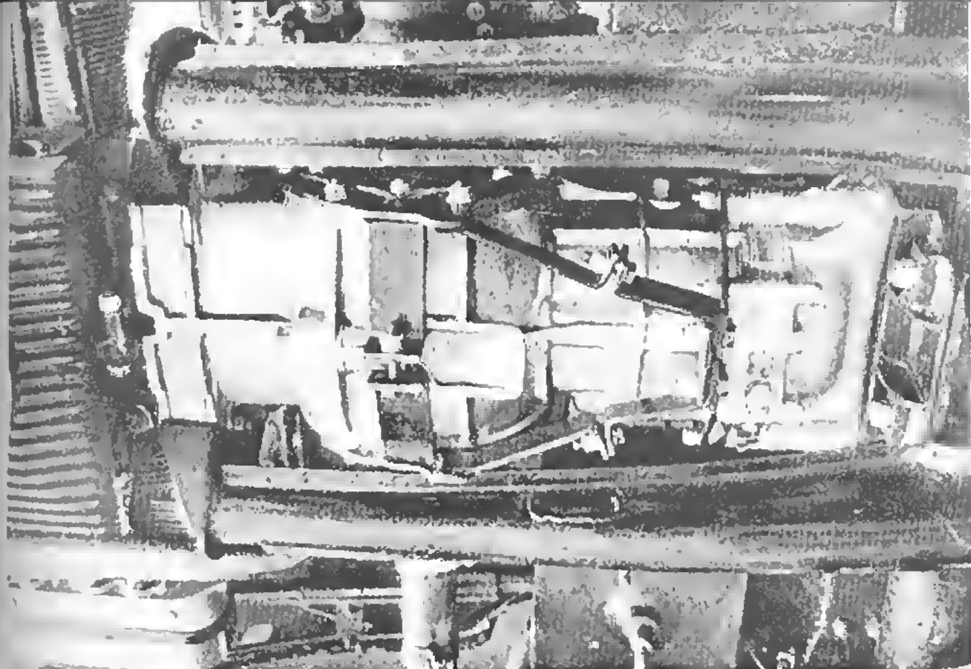
If you are using new rods, new crankshaft and new pistons, there are many things which you can do to these, including balancing the rods end-for-end and for overall weight, then getting them shot-peened, balancing the crank, and assembling the pistons to the rods so that they can be aligned. Be sure to mark everything carefully whenever you assemble for checking and then disassemble. You want to be able to recreate the combinations which you checked as being right. Don't balance the pistons until you've made a trial assembly of the engine.

Cylinder-head work is another time-eater and you may want to rework a set of new or used heads to reduce delays from this source. Some buy a complete engine and install it while reworking their "good" engine, or rebuild it instead.

Much of the special detail for assembling the VW engine in high-performance form has been carefully detailed in the preceding sections of the book, especially in the sections on heads, pistons, cranks, cams, and cooling/lubrication/breathing. When these previous recommendations are combined with an intelligent application of the details in the Workshop Manual—*which you must have to work on the VW if you want to become really expert*—you should

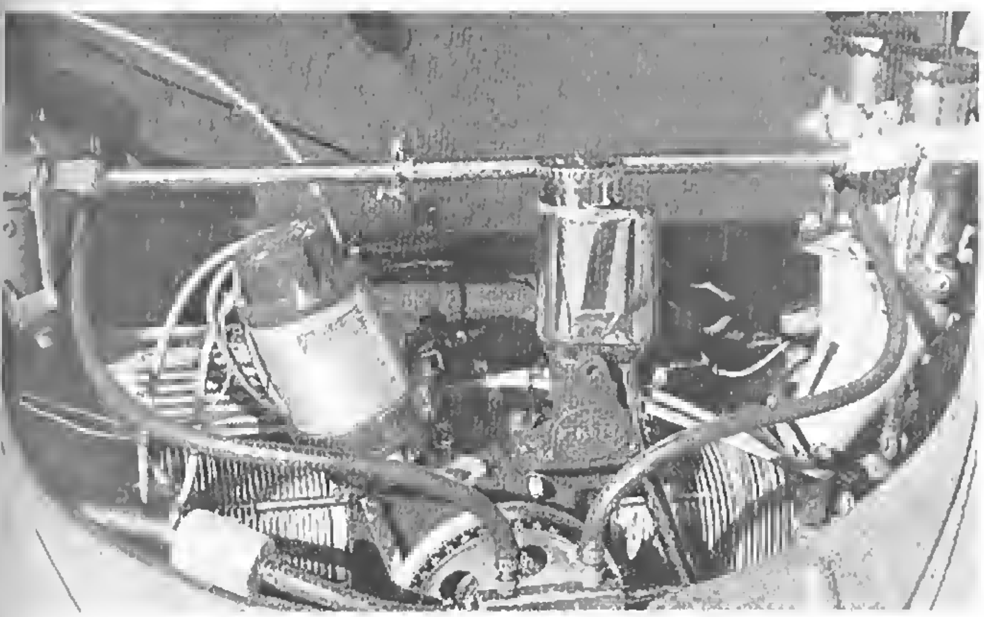
Dick Cepek sponsors Miller-Havens single-seat off-road racer which has been a consistent winner, including 1st overall in the 1970 Baja 1000. A quick glance won't reveal why this engine is so consistently trouble free. But—study it and you'll note that there's nothing extraneous. Everything is kept clean and simple. Note dual coils, Berg throttle linkage, Zenith carbs, remote oil cooler and VW auto-stick-shift oil pump. Note asbestos-wrapped headers.





EMPI Racing & Tech Director Darrell Vittone has convinced hundreds of thousands of drag fans what can be done with a VW. 48 IDA Weber carbs on EMPI manifolds and heads feed mixture to EMPI/Mahle 88 mm forged slipper-skirt pistons hung onto EMPI/SPG 82 mm roller crank. 311 oil cooler hides behind Joe Hunt magneto. Engine is tastefully finished in black-crackle enamel. Car's Porsche transmission will be replaced with 900 Series racing transmission for 1971 season. ET's of 11.6 seconds have been obtained with 116 MPH terminal speed at 1/4-mile drags. 1/8-mile ET's of 7.51 seconds and 93 MPH have been posted.

Darrell Vittone used this transaxle "girdle" to keep his gears together during the 1970 drag season, will switch to Porsche 900 Series racing gearboxes for 1971. Note that the girdle clamps the Porsche transaxle together both cross-wise and end-wise. Solid transaxle mounts are used on this machine. Dune Buggies and Hot VW's photo by Joe Rusz.



end up with an engine which gives outstanding performance for its size. Let's consider the items which you should assemble before working on the engine.

1. Workshop manual, preferably the "Volkswagen Service Manual 1300/1500," plus another if you have a fastback/squareback/notchback.
2. Torque wrench, 3/8 or 1/2-inch drive, at least 0 to 600 pound inches. A click type which lets you dial-in the desired setting is preferred. Any torque wrench can be checked for accuracy on a valve-spring tester.
3. Dial indicator with 1-inch travel, suitable holding devices.
4. Degree wheel or degreed crank pulley.
5. Ring compressor, take-apart type as made by All-Power Automotive Products.
6. Plastigage, Type PG-1, 0.001 to 0.003-inch capacity, for checking connecting-rod-bearing fit.
7. Lubriplate, High-Temperature, Ford COAZ-19584, 1.75-ounce tube for lubrication of crankshaft seal/s, plus initial lubrication of heavily loaded parts such as the rocker shafts.
8. Moly lubricant for smearing onto camshaft and lifters.
9. GM's Engine Oil Supplement (E.O.S.) or Ford's Oil Conditioner C2AZ-19579-A for use in initial oil fill of the engine and for use in assembly of bearings, lifters, etc.
10. Gasgacinch or Permatex Aviation Form-A-Gasket No. 3 for sealing case halves, cylinder bases, oil-pump body to case, etc.
11. Loctite for studs, cranknuts and connecting-rod nuts, especially.
12. Carburetor and parts-cleaning fluid, 5-gallon can, and a 10-gallon tub to put the case halves in.
13. Flywheel locking device, used when removing or installing the crankshaft/fly-

wheel gland nut. You can make one of these, buy a Baum tool, or use a spark plug wrench from the VW tool kit if the engine is fully assembled.
14. Metric socket set 3/8-inch drive and metric end/box wrenches.
15. 3/4-drive 1-3/16" and 1-7/16" sockets, (fit pulley/gland nuts, cheaper than metric), 3/4-drive bar, and a 4-ft. length of steel pipe to slip over the bar for crank nut tightening.
16. Child's modeling clay for clearance checking in heads.
17. A 1/2 X 1/2 X 6 inch ground tool bit (such as REX) is very handy for measuring deck clearances when used with a feeler gage.
18. A bench or floor-mounted engine stand is almost a must if you are going to make a hobby or business of working on VW engines. The bench units start at about $25. Weld a flywheel gland nut to the engine stand so that you'll have a handy holder for the crankshaft when fitting rods onto it.

Dave Van der Beke's 1961 VW sedan campaigned with Porsche power through 1969, then switched to more potent VW and faster times of 11.95 seconds and 109 MPH in "I" Gas for 1970.

Now how are you going to get all this stuff together on a Saturday evening? It would be tough in Los Angeles or Orange Counties where some parts houses are open 24 hours. Getting the torque wrench alone could take a week if you do—as I do—buy from a mail-order house to get the cheapest price on name-brand merchandise. I have a 3/8-inch-drive Sturtevant torque wrench (0 to 600 lb. in./50 lb. ft.) that cost about $10 from Montgomery Wards'—even though the catalog did not say who makes it, the outline of the maker's trademark is on it. Sears has Oldak 1-inch dial indicators for about $16 in their hand-tool catalog. The degree wheel could easily be a Santana pulley which is available through all VW speed parts houses and through J. C. Whitney and Warshawsky. Both stock and small "power" sizes are available with the degree indication. The workshop manual will be available where you bought this book—or should be.

Cleaning engine parts is a chore. After several years experience with motorcycles, Corvairs, Porsche and VW engines—I can assure you that the $20 you'll spend for a pail of carburetor cleaner makes sense. Steam cleaning or high-pressure stuff at the car wash won't get the job done, but it will get off the gross accumulations which would muddy up your expensive parts cleaner. The major portion of the dirt and grease encrustations should be taken off with solvent and a brush or at the local quarter-in-the-slot car wash so that you'll avoid crudding up your expensive cleaner—which will then take off the fried and baked-on grease and varnish. Put the crankcase in a wash tub, soaking first one half and then the other. The same applies to cylinder heads and this stuff does soften the carbon so that you can scrape it off very easily.

Crankcase nuts are either of the sealing type or may have flat washers under them. If you are taking apart a case which had the sealing-type nuts, be sure that you pick out all of the tiny pieces of the sealing material with a scribe or ice pick before trying to get the case apart, because these can wedge into a hole and make the cases almost impossible to split.

When you are disassembling the engine—put aside that stud puller until you have determined that there is some real reason to take out the studs. First of all, it is a lot of work to take them out—and more work to put them back in. And, it wears out the threads in the case—which are none too sturdy anyway. Ray Longanecker of Say Ray Foreign Auto in Palo Alto, California says, "Taking out the studs when it's not necessary shortens the life expectancy of the engine. It's better to pay a little extra for the machinist to set up so that he can do his work with the studs in place than it is to take them out. When you consider the time involved, it's almost a tradeoff, anyway." Dean Lyon points out that taking out the studs always raises the metal around the stud holes. This must be stoned off before attempting to do any precise measurements with a surface plate clamped to or under a case half. The case half with studs can be raised off of the surface plate with parallels when making measurements. Parallels need only to be slightly higher than the length of the studs.

If a cylinder stud has pulled out of the case or become so loose that its threads will obviously not withstand torquing the head in place, a "case-saver" can be screwed into the case after drilling out the hole to the appropriate size for the tap used to install the threaded insert. Note, however, that the insert should be installed prior to boring the case for installing larger-than-stock cylinders—and, the inserts should not be used with any bore larger than 88 mm or the insert will not be fully supported in the case metal.

When installing cylinder studs, Loctite them into the case to avoid oil leaks. Before installing cylinder or case studs, examine the threads with a magnifying glass to make sure that there are no rough spots or peened-over threads which could damage the case threads. Clean off such threads carefully and check them with a nut before installing them into the case.

Before you assemble the rods onto the crankshaft, check once again that all of the oil holes and check

surfaces of the crank are smooth without any rough spots or burrs. Use Cratex abrasive wheels to radius the edges of all oil holes in the crankshaft and thoroughly wash the crank afterward, using pipe cleaners to insure that all of the holes are completely free of dirt.

As you assemble the rods to the crankshaft, use a piece of Plastigage for a trial assembly of each rod so that you can check how close you are to the desired clearance of 0.0025 inch. Disregard early VW manual torque recommendations of 32-36 lbs. ft. because these values will stretch the bolts and could cause failures. Use 22 lbs. ft. torque with Loctite on the threads during your final assembly of the rods to the crank. Rods with a forging mark on the shank must be positioned so that the marks will be up when the engine is installed. 1200 and 1300 rods with bolts only should be equipped with new bolts at every rebuild and rods with both nuts and bolts should have the nuts replaced at rebuild time. Lubricate the bearings as you install them after the clearance check.

Before starting the rest of the assembly, ask yourself what may have been overlooked. Have you cleaned out the case halves, perhaps even taking out the soft plugs and tapping the case for use with pipe plugs? Has the case been modified for a full-flow oil filter that you plan to install now or later?

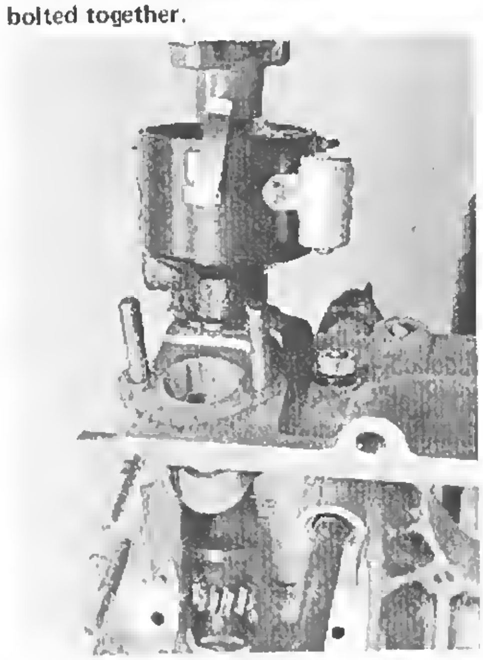
Badly pitted and scored bearings from an engine run without a full-flow filter. See cooling, lubrication and breathing chapter for installation details.

Did you remember to install the main bearings in the case and measure them after torquing the case nuts? If you are using a case which requires nuts with the built-in seals, have a few extras on hand. The seal can get separated from the nut when you screw it onto the stud.

Don't assume that the pickup tube and block passages are leak-free. Make sure that there are no leaks by holding your finger over the hole which feeds the pump as you blow into the end of the pickup tube. Any leak, however minor, is cause for stopping to find out where and what the problem is. If the tube is loose in the case, remove it, clean the tube and case hole carefully, then reinstall the tube with Loctite. If you find a hole in the block—and such things do occur—then heliarc it or fix it with Devcon "F" if you can. If not, don't hesitate to scrap the block. The oil pickup must be secured to one of the studs in the bottom of the sump, as on late-model VW's.

You may have looked at your VW case and wondered why both halves had dowel holes for the No. 2 and 3 main bearings, even though only one dowel is used for 1, 3 and 4 main bearings in your engine. At least some of the engines shipped to cold climates such as the Midwest, Alaska and the Scandanavian countries have split main bearings requiring both dowels except for No. 4, which is full-circle and uses only one dowel. The No. 1 left bearing half is slightly rotated to line up with its dowel/s, thereby placing an edge of the bearing above the case split surface.

Install distributor drive and distributor prior to laying crank. This saves later fumbling with a long screwdriver, greased washer and strong language that might annoy your neighbors. Don't forget washer under drive. There should be 0.020-inch up/down play when all is bolted together.



When your case is blueprinted to the point that you desire and you've made sure that there are no internal oil leaks, start the assembly process. Work on a clean, well-lighted table as if you were a doctor performing surgery. Consider dirt the mortal enemy of your engine. Give close attention to the use of the torque wrench. Be sure to replace the rubber gasket around the distributor base. Lubricate it so that it will slide into the case without difficulty. Install the distributor and check the distributor drive gear end play. It should be 0.020 inch. Set the distributor to No. 1 cylinder firing position (point rotor to mark on distributor case rim) and tighten distributor clamp. Install dowels for the bearings in the left half of the case and install the left half of the No. 2 main bearing. Install cam bearings. Hold the assembled crank by No. 1 rod as if the rod were at TDC position, and lower the crank into the left half of the case. This engages the crank correctly with the distributor gear. Turn the crank 1/4 turn clockwise and the crank gear is positioned for installing the cam. Install tappets and smear moly lubricant on them. Lube cam lobes and bearings with moly lubricant and check again that there are no rough spots on the cam thrust surfaces. Remember that you'll want a flanged cam bearing in each case half (requires buying two cam-bearing sets) if you are building a high-performance engine. Install cam so that its gear mark mates with the crank-gear mark. Check cam for end play and gear lash.

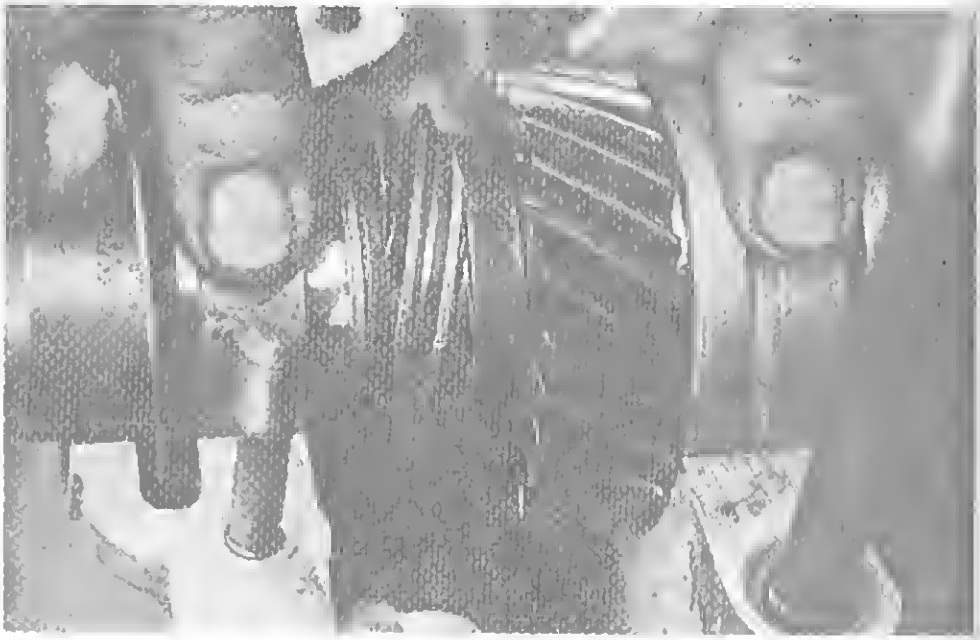
As you start to assemble the case, remember to install the cam plug at the front of the engine. If you leave it out, a massive oil leak will result, and there's just no way to put it in once you have tightened any of the case bolts. You'll have to loosen things up to install it. If you are using a camshaft with a bolt-on gear, it is important to check that there is adequate clearance between the oil-

pump body and the capscrew heads. Do this now while you can still observe what clearance exists. If there is interference, you may have to counterbore the cam gear so that the capscrews will insert further—which may also mean shortening them so that they do not extend beyond the cam flange. Check once again that you have the correct pump body with holes of the appropriate size and location to mate with the pickup and delivery holes in the case halves. 1970 and later cases have larger holes throughout and require a new oil pump body. If you are using a windage tray, install it in the left half of the case.

Use lacquer thinner to clean off all of the sealing surfaces, then use Gasgacinch sealer on all sealing surfaces, being careful to keep it away from oil holes and bearings. If your case has the countersunk areas around the studs, install the rubber stud seals around the six main studs. Also check that the oil slinger and key are installed in the crank nose.

Check that the bearings are firmly seated in the left case half. Insert the tappets in the right half and install the cam bearing inserts and the No. 2 bearing right half onto its dowel. Tilt the left side of the engine so that it is almost in running attitude, but don't make it completely horizontal or the crank could fall out. This allows you to install the right side of the case with a minimum angle so that the tappets have less tendency to slide out of their bores. Also make sure that the No. 2 bearing half stays in the right side of the case as you tap the case onto the dowels.

The assembly of the crankcase, bearings, camshaft and crankshaft unit is not a "bolt it together" process. The two case halves change relation to each other as you torque the case nuts. Ray Longanecker of Say Ray Foreign Auto in Palo Alto, California claims that you will probably find that the crankshaft will be tight at one or more points in its rotation, if you merely tighten the case together, even with the correct torque. You must proceed slowly, taking up only a few lbs. ft. of torque at a time, and checking the crankshaft for free rotation as you proceed. Start at 10 lb. ft., then tighten in increments of 5 lb. ft. to 20 lb. ft., and finish off with increments of 2.5 lb. ft. until you reach the 25 lb. ft. specification. Here's where a click-type torque wrench helps! You must check the crank for free rotation continuously as you tighten.



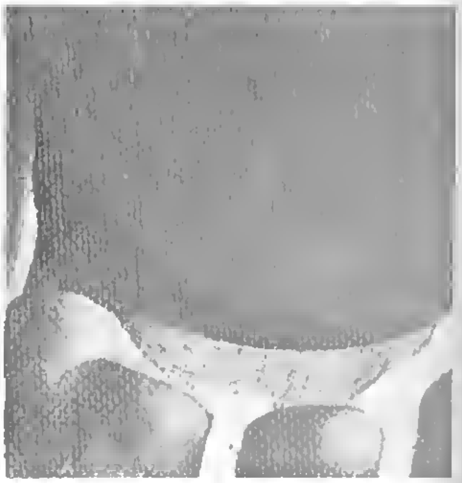
Be sure that the bearings are fully seated into the dowels and into the bearing saddles.

I have found that some engines will not stay free when the stock tightening sequence is used and a modified sequence is required to get the engine tightened up with free crank rotation. When you get to a spot where the crank does not turn freely, stop right there to see what is causing the problem and fix it then. Don't ever fool yourself into thinking that a tight spot in an engine will "wear in." That's utter nonsense! You must never hesitate to take the engine apart completely to remedy a problem and you must never, never, never grind on any part of the engine—or use a rotary file—without taking the engine apart because there's no way to keep abrasive materials and metal chips out of all of the vital oil passages if such remedies are required. That is why two or three trial assemblies of the engine are the hallmark of the experienced engine builder. These men all know that the engine will not assemble correctly the first time, regardless of all of the checking, measuring and machining that has gone into the preparation of the case, crank, rods, pistons and other parts.

Don't hesitate to refer to the shop manual as you proceed. Above all, if you reach a point where there is a seemingly insurmountable problem, stop and think about it carefully—perhaps even sleep on it—before you start making drastic changes to make it all work together.

As you turn the crank, be sure that the rods do not scar the cylinder spigots in the crankcase. You can wrap the rods with rags or otherwise protect these surfaces. This is the ideal time to check crankshaft end play because the crank will move back and forth easily in the main bearings. If you wait until the pistons have been installed, the rod-bearing friction is added, making the task a little bit more difficult. Use precision calipers or a depth mike to

Case ground to clear 78 mm stroke crank shows how not to do it. Don't take out more metal than is absolutely necessary to get clearance. Extra clearance merely weakens the case.



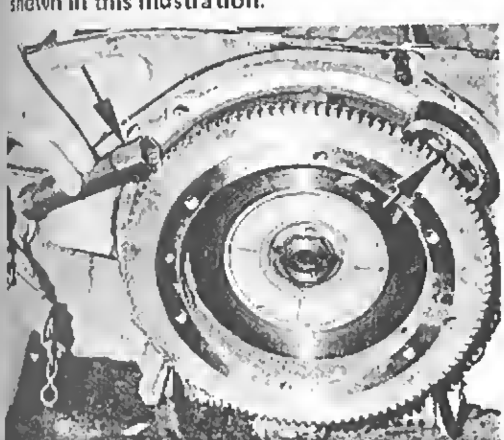
measure the distance from the crank end to the shim recess, and compare this with the flywheel recess to determine the shim-pack requirement to get the desired 0.004 to 0.007-inch end clearance. No gasket is used between an O-ring flywheel and crank, but earlier flywheels can be gasketed to 8-dowel cranks with an 8-hole paper gasket available from some of the VW speed parts suppliers. Torque the gland nut to at least 200 lbs. ft., then check crank end play with your dial indicator. If it is off, note how much so that you can add or subtract shims to get the correct play.

Or, before installing the flywheel, insert two shims, add gasket if required, and torque gland nut to 200 lbs. ft. Measure end play with dial indicator. This reading, minus the desired end play of 0.002 to 0.005 inch, is the shim thickness required for the third shim.

The flywheel seal is one of the last things to be installed before the final bolting of the flywheel into place on your 8-dowel crank with an oversize washer and modified gland nut as described in the crankshaft chapter. The end play must be checked again after the gland nut has been torqued to 250 lbs. ft. or more.

This is also a good time to install the oil pump. Insert the pump body after using Gasgacinch around the inlet and outlet holes, then insert the drive gear. Turn the engine through two or three revolutions so that the pump

Holding the flywheel so you can tighten the gland nut—or loosen it—requires either a VW spark-plug tool for a fully assembled engine, or one of Charlie Baum's tools for an engine that's being assembled. Both are shown in this illustration.



body will be centered before you bolt it in place, using VW's special sealing nuts where applicable. Check that the piston pins are an easy thumb-press fit in the rods and pistons at room temperature. Keep each piston pin with its own rod and piston because these are selectively fitted and you don't want to mix them up. If you are using a roller crankshaft, stop to check again that the distance between the pin bosses is from 1.240 to 1.280 inch, or whatever distance is called for on the tag which accompanies your SPG or SPG/EMPI crank. Clearances of the piston skirt to cylinder should be rechecked prior to installing them, and you should already have checked the fit of the rings in the grooves and the end gaps of the rings. If not, read the details in the piston chapter and make sure that all of these clearances are right.

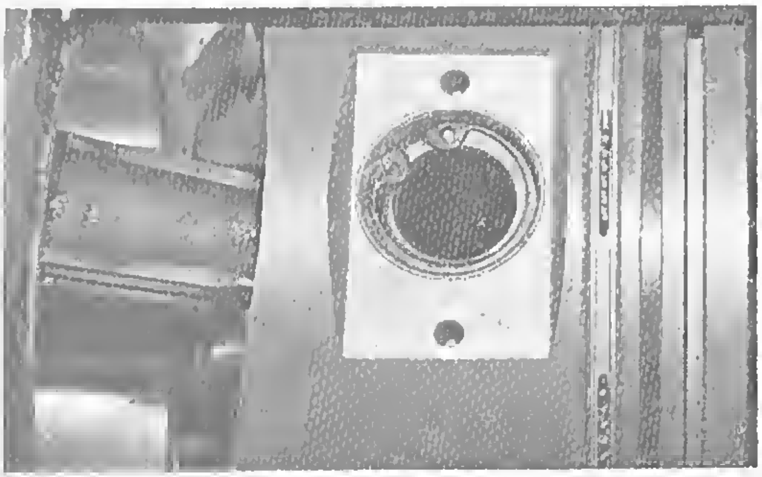
Because piston-pin holes are offset in all stock pistons and in most replacement and racing pistons, be sure that you place the arrow or word "vorn" toward the flywheel. The arrow is on the underside of the pin boss on some pistons. The offset piston pin allows the connecting rod to change its inclination and tilt the piston easily toward the opposite side of the cylinder wall before reaching TDC. Piston slap which would otherwise occur is avoided. Vee builders turn the pistons over to place the offset in the opposite direction, claiming that the 1% to 2% HP gain offsets the added noise—which they can't hear above their open exhausts anyway.

Get your bottle of Loctite before starting to assemble a VW engine. It's essential for keeping screws tight. Here it's used on the gland nut which holds flywheel to crank. Note machined steel washer.

No need to invest in a piston-ring compressor when a piece of steel band will do the job. Make it thin enough so that it can be wiggled out between the studs and piston when the cylinder is over the rings. Channel-lock pliers pull the ends of the wrap-around together to compress the rings.

A take-apart ring compressor is required to compress the rings so that the cylinder can be installed over them. If you don't have a compressor, a piece of spring steel can be used with channel-lock pliers to get the job done. Be careful as you slide the cylinder over the rings. If you meet any resistance, STOP! Take the cylinder off and find out why. Examine the piston all around its circumference. It is super-easy to break a ring land as you install the cylinder. I've known of instances where a cylinder was

Assembled VW lower end on engine stand with Berg auxiliary sump installed. Engine will be painted with thin coat of flat-black paint before installation in vehicle.



Be sure circlips are installed on both sides of piston pin before using the ring compressor to install cylinder. Ring combination shown is o.k. for street but 'way too wide for high-RPM oil control on a fast engine.

K-D 875 Piston Ringer opens rings for installation onto pistons, saves cut fingers, broken rings and blown tempers.

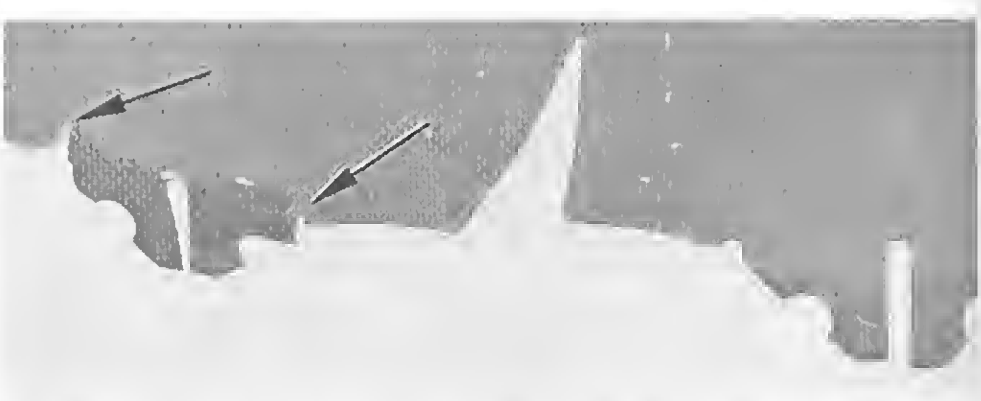
tough to assemble to a piston—then suddenly went on easily. A broken ring land was found on disassembly of the engine after trying to run it. Use sealing compound on the underside of the cylinder where it joins the cylinder. When you have installed No. 1, turn the crank slowly through one complete revolution, holding the cylinder onto the case as the crank moves the piston back to TDC. Make sure that there's no interference and that everything continues to turn freely. Now install No. 3 cylinder and again turn the crank, this time through one and a half turns so that No. 2 is at TDC. Install that cylinder and turn the crank through a full turn—then install No. 4 cylinder and again turn the crank through a full turn. You will have to hold the cylinders against the case by hand or with hold-downs as you turn the crank, otherwise they will pop out of the spigots each time a piston starts toward TDC.

Make sure that the air deflectors are in place under each pair of cylinders. These are so essential that you must not run the engine unless they are installed. Before installing the pushrod tubes, stretch them to 7.5 inches and blow into one end while holding your hand over the other end. These tubes do get leaks in them and it is much easier to fix them now than later, even though adjustable pushrod tubes are available for making repairs without taking off a cylinder head. With the heads installed and lightly tightened in place, turn the engine through several revolutions. If there is any point where binding occurs, don't proceed until you have found out why and corrected the condition.

Before torquing the head nuts in place, check again. Did you install the air deflectors under the cylinders? Did you try spark plugs such as those you will be using—to see whether there were any exposed plug or head threads with the plugs torqued in place? Remember that using more than one plug washer is *verboten* because it spoils heat transfer from the plug into the head. If you need thicker washers, read the ignition chapter again for details.

Now that you are ready (hopefully) to torque the head nuts, let's ask expert Ray Litz at Competition Engineering in Altadena, California how to get extra power from head torquing. Ray says, "A common cause of power loss is compression leaks where the cylinders fit into the heads. Because of the extreme

Adjustable pushrod tubes allow replacing a damaged pushrod tube without taking off the cylinder head. They are an essential item for the off-roader's tool kit. Bolt Enterprises and Gene Berg make them, as do other manufacturers. The finned type could be used instead of the stock tubes to gain extra oil cooling.



Air deflectors which go under the cylinders may require slight modification as shown by arrows on left deflector. Cuts allow bending supporting tab so that it will fit around big-bore cylinders to grab the studs.

temperature differential between the center of the head where cool air and fuel pour in—and the ends of the head where superheated exhaust gases rush out: an extreme tendency to warp can partially lift the head off of the cylinder sealing edge. Much power can be lost here and the head can be badly damaged.

"The popular procedure is to bolt one head on and torque it to the recommended value, using the correct pattern. Then the second head is fitted the same way . . . and the mechanic hastens to the next portion of his assembly, secure in the knowledge that he has done the head installation according to the book. Let's examine what *really* happens. First, because of tolerance build-up, natural warpage, etc., torquing the first head pulls the crankcase a little bit out of alignment. Then, torquing the second head pulls "back," tending to straighten or rearrange the case alignment. This may considerably change the torque on the first head. After numerous heating and cooling cycles as the engine is run, turned off, etc., this uneven torque will tend to adjust itself and compression leaks commonly occur.

"At Competition Engineering, we think that there is a better way: bolt on both heads *at the same time*.
1. Fit both heads on the assembly and snug down until they lie flat on the cylinders.
2. Torque one head to 15 lb. ft.
3. Torque second head to 20 lb. ft.
4. Torque first head to 25 lb. ft.
5. Torque second head to 30 lb. ft.
6. Torque first head to 30 lb. ft.
7. Alternate between heads at least two more times, bringing torque to 30 lb. ft. on each head."

Litz further cautions that no more than 30 lbs. ft. torque be used and that no sealer of any kind be used between cylinders and cylinder heads.

I know other VW tuners who would "sneak up on" the torque values in a more gradual way by using increments of 2 or 3 lbs. ft. after attaining 15 lbs. ft. on both heads. I personally feel that it's essential to retorque the cylinder heads at least twice during the first several weeks of operation, and before any competition event, even though this means taking the tin off of the engine to get to the upper head nuts.

If you are using a racing cam, you should have already made a valve-to-piston clearance check with clay on a trial assembly of the engine, as discussed in the camshaft chapter. You should also have checked the deck clearance in that same trial assembly and modified the cylinders or rods as required to get the desired deck clearance. As you complete the engine assembly, be sure that you have set the rocker-arm geometry correctly as described in the camshaft chapter. The pushrod ends and rocker shafts should be lubricated with moly lubricant or high-temperature Lubriplate mixed with the moly.

Darrell Vittone, EMPI's racing director and a formidable drag race competitor with his Inch Pincher machines, supplied a number of tips on VW assembly. "VW's special sealing-type 8 mm nuts can be used on all of the 8 mm studs which hold the case together. Loctite can be used on all of the stud threads, both in the case and on the nuts. Loctite on the studs which screw into the left half of the case seems to help hold the cases together so that they don't work against each other quite as much.

Doug Gordon's "Underdog" is a potent drag-race sedan. Mechanic-ing is by Ron Fleming. Gene Berg is driving at Carlsbad, Calif. in this photo.

Inch Pincher driver Darrell Vittone "boils the hides" as he leaves the lights at a quarter-mile drag race. Acceleration "squat" like this breaks axles! Axle travel must be limited with Transporter or 311 axle snubbers and split shock bushing on the stock shaft (retained with hose clamps). Cut off the upper dust cover for access to the shaft. Set height about 1-inch higher than normal with clamps loosely tightened on bushings. Further chassis tuning at the strip can be done by clamp adjustment, according to Gene Berg.

"If you have any area where oil sealing is a problem, G.E. Silicone Sealant or Silastic RTV will often cure the trouble. The reworked auto-stick-shift oil pump works fine, even with roller cranks which cost about 10 psi pressure loss as compared with a stock plain-bearing crank. As for special assembly tricks, other than just being ultra-careful, lapping the tops of the cylinders on solvent-wetted No. 600 paper supported on a piece of glass sometimes helps to ensure that cylinders will seal perfectly against the heads."

"I always run new engines for 2 or 3 minutes and then drain the oil and install new 30 to 50 weight Valvoline. Then I readjust the valves. This is done without exception before any load is ever applied with our Stuska engine dyno. The price of the oil that's thrown away is cheap insurance against losing an engine."

BALANCING

A number of different parts of the engine have been discussed, with specific details as to their modification for improved performance at high RPM. Now you are eager to bolt the parts together and check out your efforts on the road or in competition. But, starting to assemble the engine, it is important to get some of the parts dynamically balanced. It is important that you budget the necessary $35 or so, even if it means waiting for a few more weeks to add some external component.

VW engine parts are balanced by the factory within certain tolerance limits to provide "acceptable" performance when the engine is bolted into the automobile on its flexible engine-mounting pads. But, even if you choose to build your engine with all new stock parts, that manufacturing tolerance can definitely be improved upon for frequent or continuous high-RPM operation.

Grinding of the rods makes them match up with total weights equal, and weights of all the big-ends (bearing ends) equal, plus all the weights of the small (wrist pin) ends. The crankshaft webs may require grinding or drilling. Some of the pistons will be lightened to equal the lightest piston by turning off the balancing bosses under the wrist-pin bosses. The clutch pressure plate will probably require welding on a weight to make it right, and holes may be needed to make the mass center of the clutch-flywheel assembly the same as its physical centerline. Assembly of your engine with non-balanced all-new parts will drastically reduce its eventual life. Balancing is essential!

A smooth-running engine makes the automobile a pleasure to drive, but it is not your personal pleasure which is most important in this instance—it is engine life. Balancing these parts adds significantly to engine life. Here's why. An out-of-balance crankshaft not only shakes the engine, it also hammers-out the bearings because it constantly tries to rotate about an axis which is not the same as its centerline through the main-bearing journals. At 6,000 RPM the 20½-pound 13.8" long crankshaft will produce a 47-pound force if its mass center is offset a mere 0.002 inch. Or, a one-ounce imbalance at the outer edge of the flywheel will cause a 350-lb. force. If connecting rods or pistons are not balanced they will apply uneven forces to the crankshaft, making it tend to run in an axis other than that through its physical center. The result is reduced life, parts fail off or break due to vibration-imposed stresses, and power is wasted through excessive friction and heat at the bearings which are over-worked and overloaded to keep the out-of-balance crank in an axis where it does not want to run.

The opposed-four VW is not a "perfect" or inherently balanced design. If you live in a remote area without nearby balancing facilities, send your parts to the nearest major city where there are such facilities. Do not overlook doing this prior to starting the assembly of your engine.

Supercharging
force-feeding the Beetle

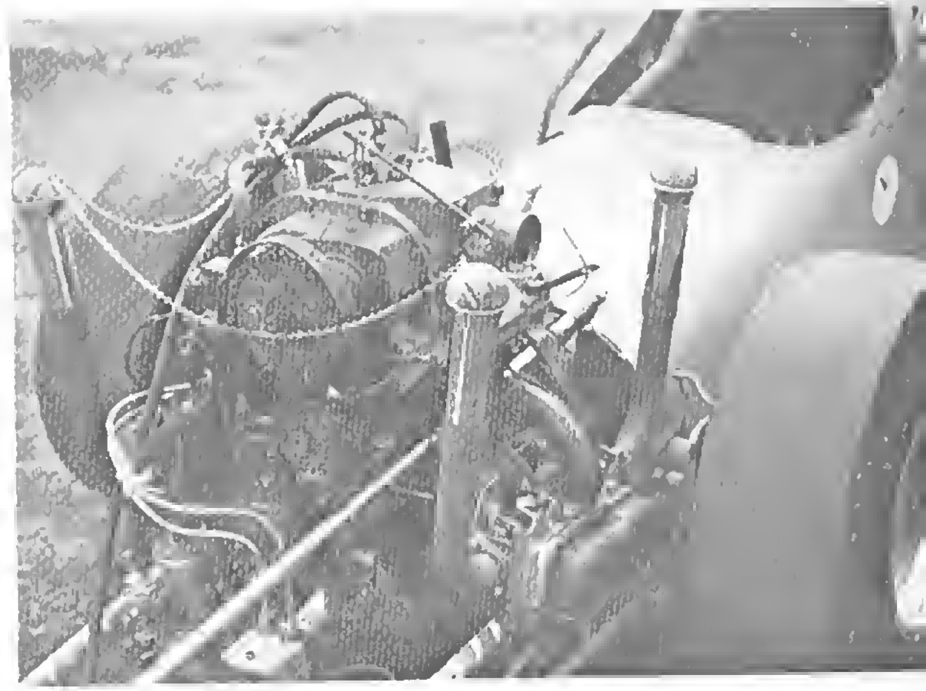
With many ads appearing for specialized supercharging equipment for the VW you may already be wondering why I haven't given a large push toward the use of such devices.

At least four superchargers for the VW have been available at one time or another in the United States. There may have been others available. And, blowers not specifically made for the VW have been adapted.

The first supercharger for the VW was the PEPCO. This roots-type supercharger worked well on the 36HP for a few thousand miles, then the "whippy" non-counterweighted stock crankshaft would tear out the center main bearing structure in the case. The PEPCO breathed through the stock Solex carb to boost the stock 36HP engine to about 50 HP and provided performance that could "be felt in the seat of the pants." Pepco superchargers are no longer manufactured, which is too bad because the blower really worked and made such a beautiful noise in the process.

Next up, or perhaps available simultaneously, was the Shorrock vane-type supercharger which breathed through a 1-1/2-inch Stromberg "CD" carburetor supplied as part of the very complete kit. These superchargers were once imported into the U.S. by Empi. Now you'd have to buy directly from the maker at a price of about \$280, plus approximately \$50 for insurance and freight.

Expect to pay the customs people another \$35 or so duty for the privilege of importing the kit. These superchargers are beautifully engineered and constructed. Some of the original Empi machines were Shorrock blown to outstanding performance records, even before some of the more exotic equipment items became available. The Shorrock is quiet and can be said to be "streetable." It is factory-equipped with an adequate mounting which eliminates the need for constant attention to belt tightening and applying belt dressing. As an indication of what can be expected on these blowers, published results in

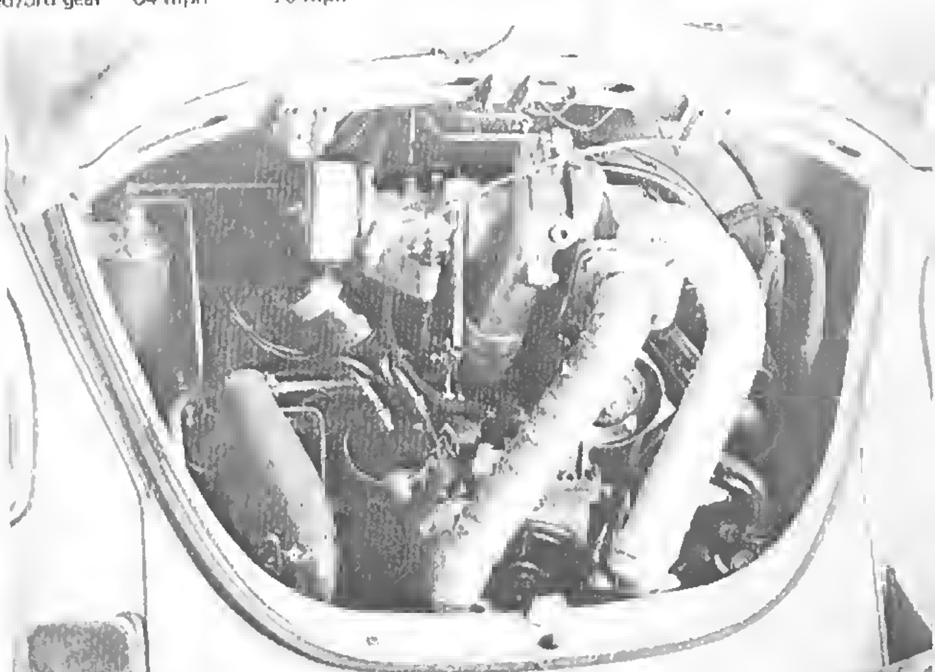


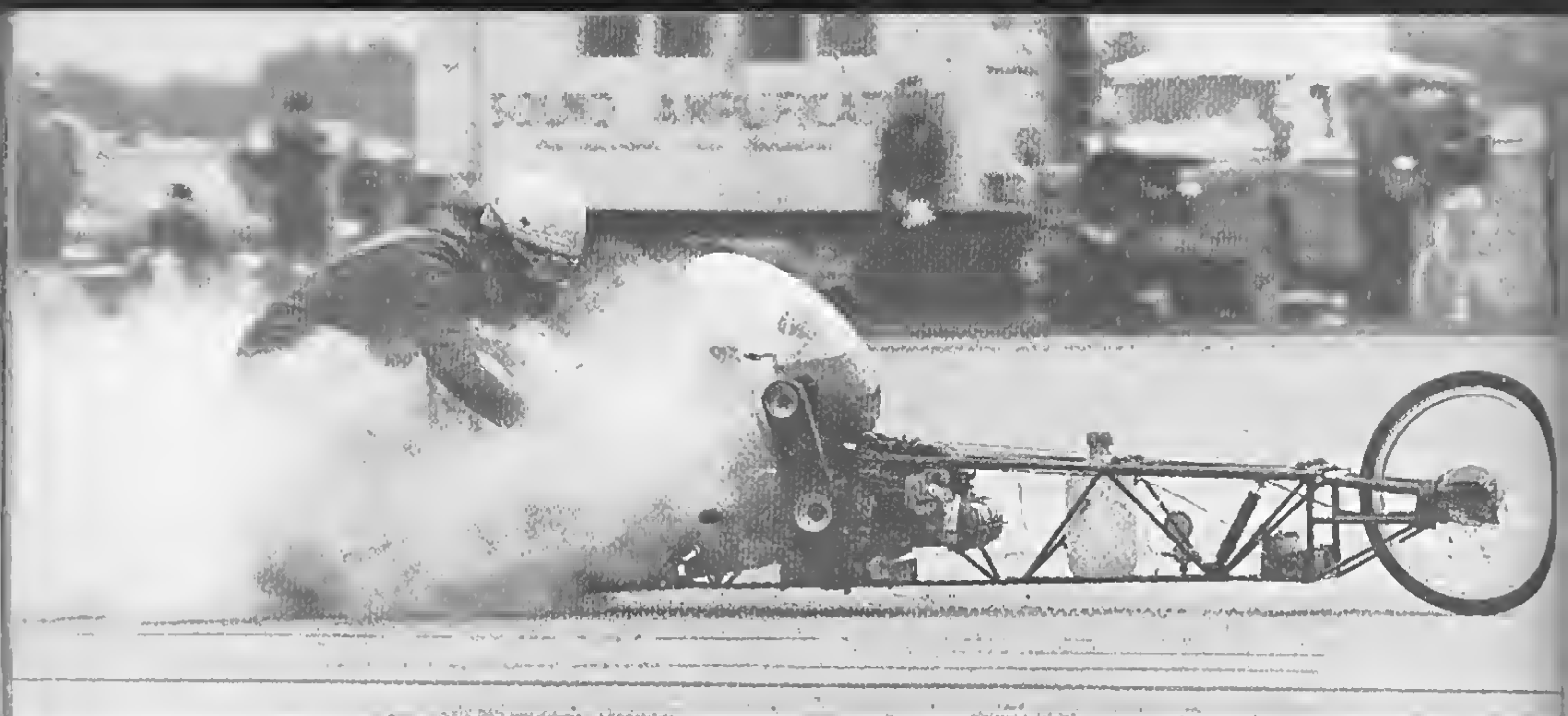
San Jose, California VW specialists Vern Luce and Tom Lazio built this blown VW dragster from the ground up. 1500 cc engine was stock except for special camshaft and 271 GMC tractor supercharger. Home-brewed fuel injector was supplied alcohol by Cessna 172 fuel pump. VW transaxle was subsequently replaced with Valiant rear end and 3-speed automatic. Best times of 105 MPH in 13 seconds showed that chassis bugs were spoiling car's potential.

English publications showed that an otherwise-stock VW 1200 equipped with the Shorrock performed as follows:

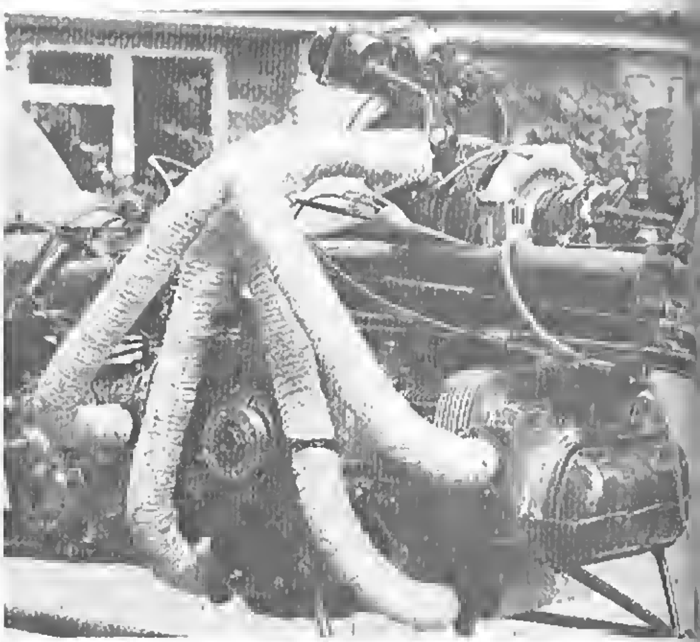
Acceleration	Stock	Shorrock-blown
0 to 30 mph	6.2 sec.	5.4 sec.
0 to 60 mph	27.5 sec.	18.0 sec.
Top speed/4th gear	73 mph	89 mph
Top speed/3rd gear	64 mph	76 mph

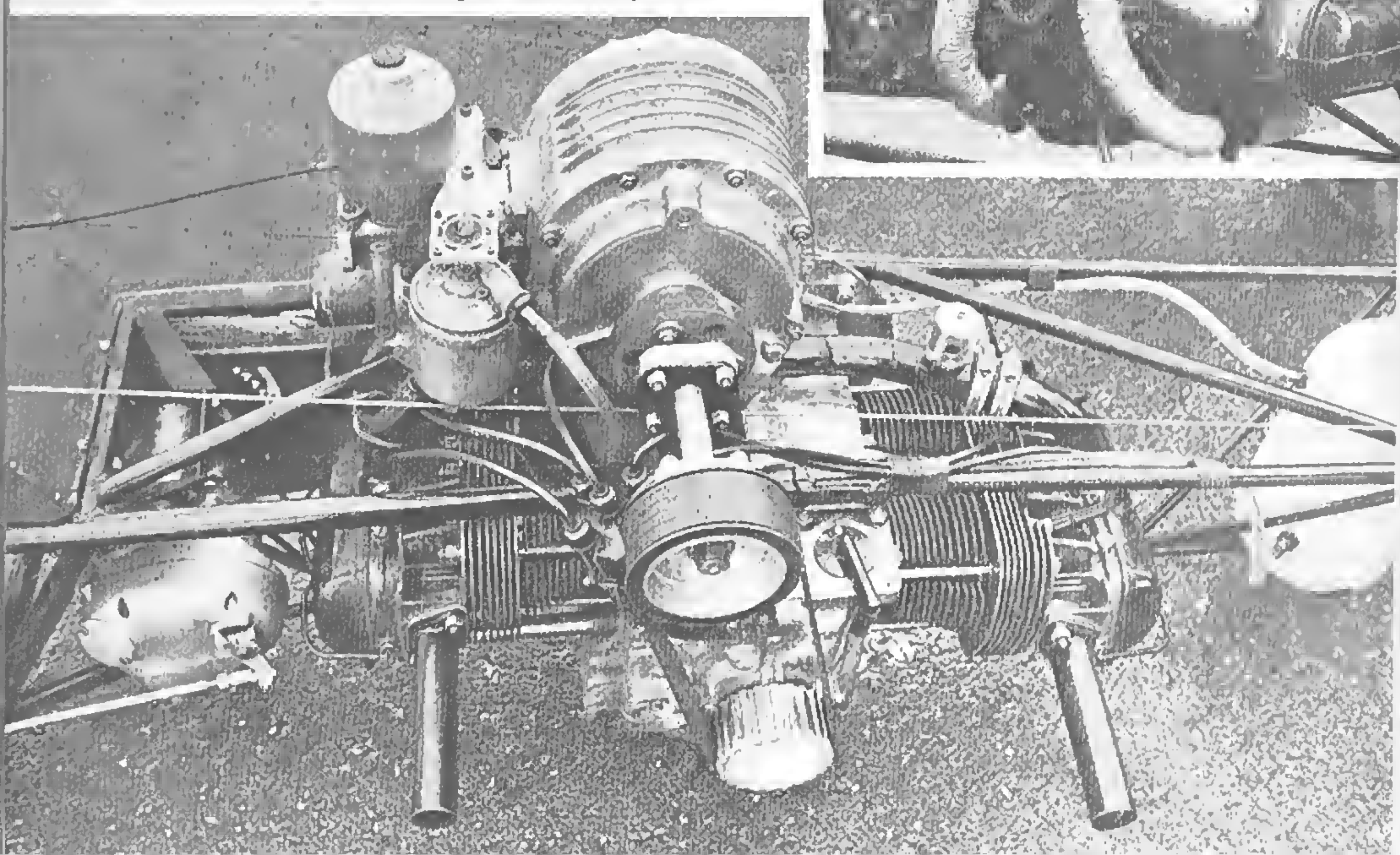
Rajay exhaust-driven turbosupercharger is quick way to add HP. Extra dowels will be needed in the crank and water injection should be used.





9.81-second standing-start quarter mile. How's that for a VW-powered machine? Here's Dave Lecoq blasting the Drag-Waye special off the line at the Elvington Drag Strip—that's in England—in November 1969 for a 155 mph run. Clive Waye's bike has 8-ft. wheelbase. Shorrock supercharger huff 'n puffs 20 psi boost to Mahle pistons in 1287 cc engine with 8:1 c.r. Note Gilmer-type toothed drive belt. 2-inch SU carb feeds on methanol (no nitro!) supplied at 3 psi from plastic bottle regulator-pressurized from frame tubes pumped to 50 psi. Engine started life in the bike as a 40 HP sleeved down to 980 cc with surplus Royal-Enfield bike pistons set at 5.5:1 c.r. Tiny "watchwinder" hustled through the quarter at just 12.1 seconds. Photo of turbocharged version shows some of the development work that always goes into a vehicle of this sort. Turbo experienced too much lag off the line for quick ET's.





Gene Berg tells us that he has installed these blowers on Sno-Cat tracked vehicles for dramatic improvements in top-speed. These snow vehicles run 17 mph faster when the Shorrock is installed with no other changes. That's a performance improvement that's hardly to be sneezed at.

One possible drawback to the Shorrock is the fact that a small amount of extra oil is injected with the gasoline/air mixture to lubricate the vanes. Extra oil leads to a hot-burning mixture which can promote detonation and running on . . . especially in an air-cooled engine. This would not be a problem if the Shorrock is installed and operated according to the instructions which are supplied with the unit.

The fact that EMPI's early Inch Pinchers got fantastic performance from the VW before exotic speed equipment became available says a lot of plus things about Shorrock Superchargers. They are distributed by Allard Motor Co., Ltd., 51 Upper Richmond Road, Putney SW 15, England.

One supercharger, the Judson, has been widely sold for Volkswagens for years. Because these rely on the manifold as a mounting device, belt slippage can be a problem unless some mighty hefty props are custom-made to hold the shaft parallel with the crankshaft. The plastic vanes in the unit require large amounts of oil from an upper-cylinder lubricator, so modified engines might get into detonation problems. I have not seen any of these blowers running around California, which is the hotbed of VW performance. Although the price is low, you may want to talk with someone who has used a Judson successfully before making the investment.

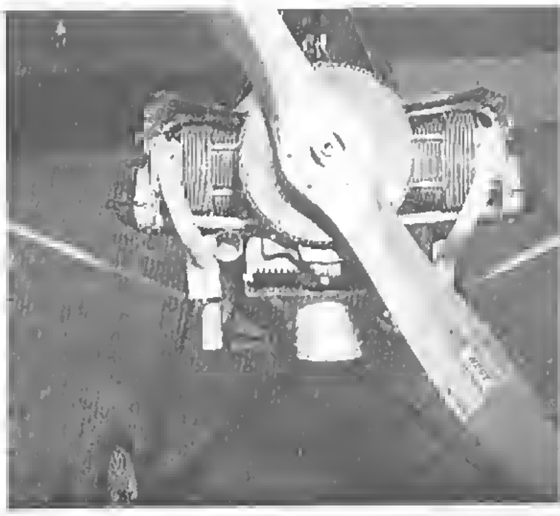
At the end of 1970, another supercharger appeared on the VW performance horizon: the exhaust-driven ex-TRW turbosupercharger by Rajay Industries, Inc., of Long Beach, California. This impressive device pumps the VW 1600's output from 44 HP to about 55 at 4,000 RPM—and by 5,500, the VW stable finds itself with 75 horses trying to get out through the clutch. Because these $400 kits are carefully engineered and precisely made by the same men who successfully turbocharged Corvair Spyders, you can be sure that you are buying high-quality merchandise.

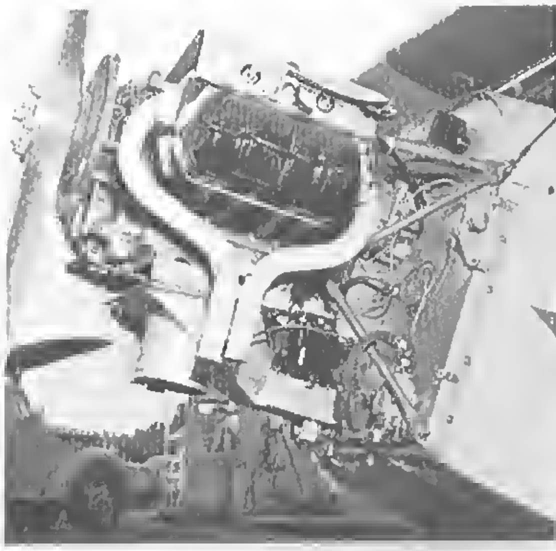
The exhaust-driven turbo has a lot of things in its favor—not the least of which is the fact that no extra oil ever has to be added to the incoming fuel/air mixture. And, the HP that you gain is almost free because nothing is stolen from the crank to turn the impeller—exhaust that was already leaving does that on its way out.

Although Rajay claims that the unit simply bolts on—I'll have to recommend that you add the extra dowels to the flywheel/crankshaft connection before making this "bolt-on" modification. With this much HP available—you'll be using it, so get the oil cooler out of the engine fan housing so that left-side cylinders will have a chance to live with the increased heat. Don't use a power pulley with this installation because your engine will need all of the cooling air that it can get.

Although the supercharger comes in nicely at 2,800 RPM, that's not soon enough for some of us who will turn to Crown Manufacturing for modifications to bring the boost in a lot sooner. One of their water-injection units should also be used because a good-working turbo whistles up enough boost to get your engine into a detonation condition. Water injection keeps this from happening.

Mr. E. H. "Holly" Fletcher of Aero Flight, Inc. in Troutdale, Oregon has this Heath "V" which was built in 1932 from a kit made by Heath Aircraft Co. of Chicago. Power is a 1265 40 HP VW with Bendix-Stromberg carb and Bendix Scintilla magneto—both on Fletcher adapters. Carb always gets warm air from stove on right-side exhaust. Hegy prop turns 3,300 RPM when plane is in the air . . . is mounted on a hub lapped to a 3° taper machined onto end of crank. High-shear locking pin holds special high-tensile bolt in place. A thrust bearing is used for the No. 3 main so that prop strain will not carry all the way through the crank. Note extra one-quart sump addition. Tops and bottoms of cylinders baffled for cooling.





Porsche engine for your VW?

a VW or Corvair might be better

When I hear an uninitiated VW owner express a fond desire to install a Porsche engine in his bug, I know that's because he does not understand what's been happening in the VW high-performance field. And, he's probably never priced Porsche parts, either. Porsche owners who become performance nuts find that there's very little equipment for their four-cylinder engines (which aren't so powerful, it turns out) and turn to an expensive 911 six cylinder —or convert to Corvair power. Porsche four-cylinder engines, incidentally, will not produce as much HP—even with super tuning—as a hotrodded VW.

Having owned a Porsche Super 90 roadster which I switched to Crown-type Corvair power with a 2,880 cc (176 cubic-inch) engine—and having driven modified VW's—I'd have to recommend that you either hot-rod your VW engine or change to a Ralph Nader special.

But you may not be easily convinced, so let's examine the situation further. If you find a used Porsche engine, even at $500, the chances are good that it will not be newer than eight or nine years old and will be ready for one of the most expensive rebuilds required by any engine. $500 to $1,000 is not an uncommon figure for a Porsche stock rebuild with no performance goodies whatsoever.

If parts are required, compare a VW head at around $41 to a Porsche one at $150, a VW crank at $57 to a Porsche one at $250 and one replacement piston and cylinder—VW at $23 versus Porsche at $56. Those facts alone should make your wallet pucker.

When you install a Porsche engine into a VW sedan, all of the engine tinwear must be cut away at both sides and the back. The tinwear must be reconstructed after the engine is installed so that none of the exhausted hot air from the engine will be recirculated through the cooling system, just as you have to do with the VW engine.

The Porsche heater boxes do not fit, so new ones must be fabricated by grafting on VW parts. Because a Porsche muffler will not fit into a sedan, you'll have to modify its width or buy a special VW extractor exhaust with Porsche flanges and dimensions.

You may discover that there is a valve-cover clearance problem when you measure the engine width. This requires additional body modifications.

Naturally, you'll want the starter and flywheel gears to mate, so you'll have to get a Porsche flywheel with the appropriate number of teeth. If you are so fortunate as to obtain a late-model Porsche 912 Series engine, then you'll have to bolt on an earlier Porsche 6V flywheel with a 180 mm diaphragm clutch with a built-in release collar in the diaphragm, available as a non-genuine part A10-470-GM from suppliers of foreign car parts. The 215 mm Porsche clutch that looks so desirable does not mate with the VW. However, if you are making the installation into a 12V-equipped VW, you can use the earlier 6V 180 mm Porsche flywheel after you equip it with one of Crown Manufacturing's 130-tooth 12V starter ring gears.

How much time does it take to install a Porsche engine in a VW? One dealer who has installed numerous Porsche industrial engines in VW's figures that at least two days should be allowed to accomplish all of the minor changes and get the engine installed into a customer's car—and this is with everything readily at hand in the parts bins and using skilled mechanics who have done the job previously.

PORSCHE TRANSAXLES

Installing a Porsche transaxle in your VW is a quick way to start broke and stay that way—unless you are a professional racer with unlimited backing. In the first place, the Porsche tranny doesn't fit directly in place of the VW component. Second, you have to make a special shift housing. Third, you have to fabricate mounts for the thing—and finally, you have to make sure that you get it into the chassis straight and true. Certainly there are special gears for the Porsche. But before you get too excited about the prospects of being able to tailor a gear box to your exact requirements, price the parts. A ring-and-pinion gear set—which often fails in drag racing—costs $150, not including the carrier. By contrast, the 4.375:1 VW ring and pinion costs a mere $43. So, if you have chosen a VW to keep your racing costs down, don't rush down to buy a Porsche gearbox (even a used one will probably cost you $300 or so) until you have given full consideration to the close-ratio gears which are available for the VW, the beefing tricks which are available from Crown Manufacturing, plus improvements you'll get through precision rebuilding for longevity—by VW specialists.

If you can break a VW transmission, the chances are good that you'd break a Porsche as well. Some people could break a crowbar in a sandbox.

How to install 1300/1500/1600 engine in your pre-1966 VW

simple if you know the tricks

What do I have to do to install a late engine in my early VW? That's a commonly asked question by people who have the vague notion that there probably are differences which make the question worth asking before going on a parts-buying expedition.

It's all very easy when you know how, so I consulted with expert Ray Longanecker at Say Ray Foreign Auto in Palo Alto, California. Gene Berg Enterprises in Orange, California also helped. They provided a lot of details that should make the task super-simple, even for a novice engine swapper.

First, the swapper needs to answer the question, "Stick with 6V or change over to a 12V electrical system?" Once that question is sorted out, the rest falls naturally into place. But if you go shopping for an engine before you have the answer, you'll buy parts you don't need—or not arrange for parts which could have been obtained at little or no cost if you had made them part of "the deal."

ELECTRICAL: 6V OR 12V?

Sounds simple, doesn't it? See if it still sounds as easy to answer after you've read about all of the details which are involved. I know what your first thoughts will be because I have made 6V to 12V changeovers. You are probably thinking, "Sure would be nice to have a better starter and generator with fewer miles on them than my 6V stuff which needs rebuilding anyway—and 12V batteries aren't all that expensive, either." But perhaps you should add up all of the details—and the $$ which they represent—before deciding. However, if you will have to buy a clutch—and a 200 mm type comes with the 12V engine you are buying—that could be sufficient reason to switch.

For instance, when you are dickering to buy the engine, remember that the 12V flywheel has 130 teeth which will only mesh with a 12V starter. So, if you decide to switch to 12V, point out to the seller—after you've nailed down the price, preferably—that he of course understands that the flywheel, starter and clutch have to be included because there's no way to start the engine unless you get the starter that comes with the engine—because *it is different.*

And the price could be very friendly, indeed, if you can get all of the 12V stuff that you'll need at the same time and place.

Here are some things to consider:

1. 12V battery to fit in the holder you now have, or you may have to arrange a new holder or battery box—or modify the one that you have in the car.
2. 12V starter required if you keep the flywheel that should come with the engine, because the ring gears on the 6V flywheel are designed to mesh with the 6V starter and vice versa for the 12V pieces. Flywheel installation is separately discussed. 12V starters are easily identified because they have a 0.430-inch-diameter shaft, compared to the 0.490-inch-diameter of a 6V starter.
3. A 12V generator should come with the late engine. If you stick with the 6V system, the 6V generator will fit onto some of the late engine generator stands if the replacement engine is equipped with a 3-1/2" diameter generator, or you can use your 1200 VW generator stand.
4. 12V lamps for instruments, dome light, headlights, taillights, and a 12V flasher for turn signals, etc., are available from the VW store, or the friendly junkyard may be able to give you a very favorable price, including a 12V battery, perhaps.
5. 12V radio and windshield wiper motor will not be required if you install resistors in series to provide the correct voltage for the load which these need. Don't buy Volt-A-Drop resistors and expect them to do the job because the size of the resistance must be fitted to each electrical device's individual load requirements. A 4.5-ohm 25-watt resistor in series will handle most wiper motors. If the resistor is not quite right, the windshield wipers will not shut off because they will run so fast that they will sweep past the parking switches. Transistor radios will work with a 7.5-ohm 10-watt resistor. Old tube-type radios take such a big resistor that you may decide to switch to a transistor type. You'll not find these big resistors in an auto parts house or radio repair shop. Get them from an electronics supply house. If you have an electrically trained friend, he may be able to show you how to use dropping diodes instead of resistors. These supply constant voltage, regardless of varying load, but must be mounted on aluminum heat sinks. The 6V horn works fine on 12V, as does the electrical gas gage on busses. All 1967 and later 1500/1600 engines are equipped with 12V generators and 130-tooth flywheels to mesh correctly with the 12V starter. Some few 1966 engines (1300) had the 12V equipment, but these are rare. Rather than counting flywheel teeth, look at the right side of the generator, just outside of the fan housing. Numbers stamped into the generator will help you identify the engine as 6V or 12V. A 12V generator will have a long part number which includes "14V 30A 20." 14V is the output voltage required to charge a 12V battery. 30A is the load rating (in amperes).

12V generators are available in two diameters, with the larger (4-1/8") being the highest-output unit and therefore the most desirable.

6V generators will be marked 7V 50A 28, or another number instead of 50A if they are a low-output unit. 6V generators are also available in two diameters: 3-1/2" and 4-1/8". The small diameter was used on 36 HP and 40 HP, but the larger diameter unit (higher-output) was available as standard equipment on 1966 sedans and busses.

Generator stands are available for both diameters. The large-diameter units use the same stand for both 6 and 12V, and the same is true for the small-diameter parts.

If you keep the 6V system, just transfer your pre-1966 parts generator with fan and stand, coil, and carburetor with its 6V idle fuel shutoff—to the new engine. If your car is a 36 HP model, the generator, coil and carb can be transferred, but you'll need to buy the appropriate generator stand (generator stand is part of the engine crankcase casting on the 36 HP). The old 36 HP generator (identifiable by a 1/2" wide slot for brush inspection) is a low-output unit which you'll want to replace with a later 7V-50A unit (13/16" wide brush slot).

Arrows indicate where case has been rotary-filed away to clear larger diameter of 12V flywheel. Engine can be inserted part way into transaxle housing and the crank rotated from the pulley end with a wrench to make marks showing where interference is occurring.

STARTER, FLYWHEEL & CLUTCH

Flywheel & Starter

12V System - Use the 130-tooth flywheel with a 12-volt starter. If the starter is being installed in a transaxle which was originally equipped with a 6V starter, increase the size of the starter shaft to 6V diameter with a $3.50 Crown adapter bushing, P/N 5054. Grind out the transaxle housing for flywheel gear clearance. This is easily done with a rotary file in a 1/4-inch drill. Remember that the transaxle housing is magnesium. That metal catches fire and burns with a vengeance. This is the metal used in incendiary bombs! Keep the chips cleaned away. It may be tempting to use a body sander with a coarse disc, but the fire danger is too great to recommend it.

The 6V starter/flywheel can be used on 12V, but you may have clashing of the starter against the flywheel teeth unless the solenoid is changed to a 12V.

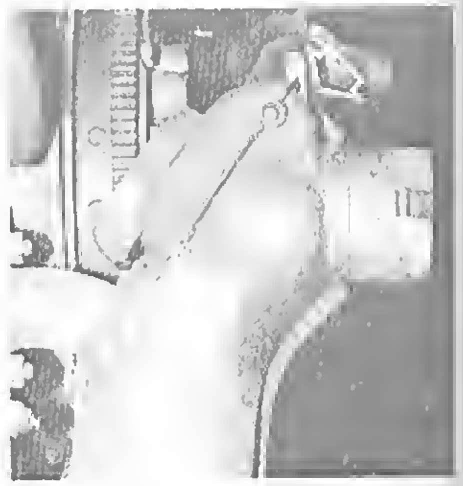
6V System - Any 1200 flywheel can be used, but the 109-tooth 6V 1966 O-ring-style flywheel is preferred—or use one of Crown's lightweight flywheels with 109 teeth. A 36 HP flywheel cannot be installed on the larger engines. Be sure to check the crankshaft end play when installing another flywheel.

Clutch

If you are using your old 6V 1200 flywheel, or if you purchased a new 6V flywheel, use a 180 mm 211 (transporter/bus) style pressure plate. Or buy a 200 mm 6V O-ring-style flywheel from a 1966 bus, P/N 211 105 271C, and use the clutch which comes in the engine you buy. If you buy an engine with either the 180 mm or 200 mm clutch in the 12V flywheel, use that clutch. The 200 mm, as supplied on 1500 engines starting in 1967 (53 HP SAE), is the better of the two.

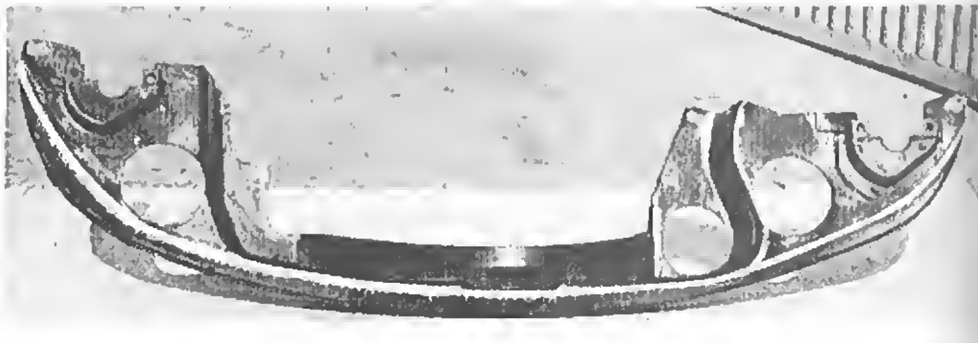
BODY & SHEET-METAL MODS

The sheet-metal at the back of the new engine must be trimmed so that it fits inside of the body. An accompanying photo shows where to trim this piece. New seals must be installed so that none of the exhausted hot air from the engine's cooling system and none of the exhaust itself will be recirculated through the cooling system—for reasons detailed in the cooling/lubrication/breathing chapter. Check that there is clearance at each side for the rocker-arm covers. Clearance may have to be provided on some models. 1960 and prior bodies must be dimpled on each side to provide clearance for the heater boxes.



Heater box of late engine may hit early body at forward edge (arrow). Dimpling body provides clearance.

The heater-duct diameter in the car may be different from that on the heater box at the front of your engine. Don't despair, VW has a stepped connector muff with the correct diameter at each end for the mating parts. If your car is a 61-64 model with frayed insulation on the inside of the heater duct, replace the muff with the later style which secures the insulation so it can't fray.



Rear shroud from late engine needs trimming on engine side of line. Be sure to reseal compartment so no hot air can recirculate into cooling system. into cooling system.

EXHAUST SYSTEMS

The stock muffler will fit in place under all of the VW sedans. However, not all of the special exhaust systems will fit, especially under the older body style (1951-59). Any exhaust system which is wider than the stock one will probably give clearance problems in the earlier bodies.

TRANSAXLE SWAPPING

Should you be making the installation in a 1960 or earlier VW, chances are good that you'll want to consider using a 1961 or later tunnel-style transaxle with its all-synchromesh gears including first gear. I've provided the details you'll need for that, too.

The hotrod enthusiast reader of this book is primarily concerned with the four-speed transaxles used in the "bug" or VW Type I sedan, the Variant and the several versions of the VW truck (transporter). There are two different swing-axle transaxles. Prior to 1961, the transaxle case was split, much like the engine case. Beginning with 1961, the main case is a single casting. This transaxle is referred to as the "tunnel-type."

Thus, you can quickly identify the transaxles by looking at them. If you spot one with four universal joints (one at each wheel and one at each side of the transaxle)—that's either a '68 Auto Stick Shift or a '69 or later model. These have the desirable synchromesh first gear, but installation into an early floor pan requires welding on a bracket at each side.

The main disadvantage of the pre-'61 split case is not the case itself, but the small pinion bearing. An additional disadvantage is the weaker, non-synchromesh straight-cut first gear. Because of this non-synchro gear, you should stop the car to engage first gear. Or, if you are adventurous or rich, you can jam it in while the car is still rolling and take a chance that the gear won't break as you force it into mesh while the main-shaft is still turning. Avoid this transaxle.

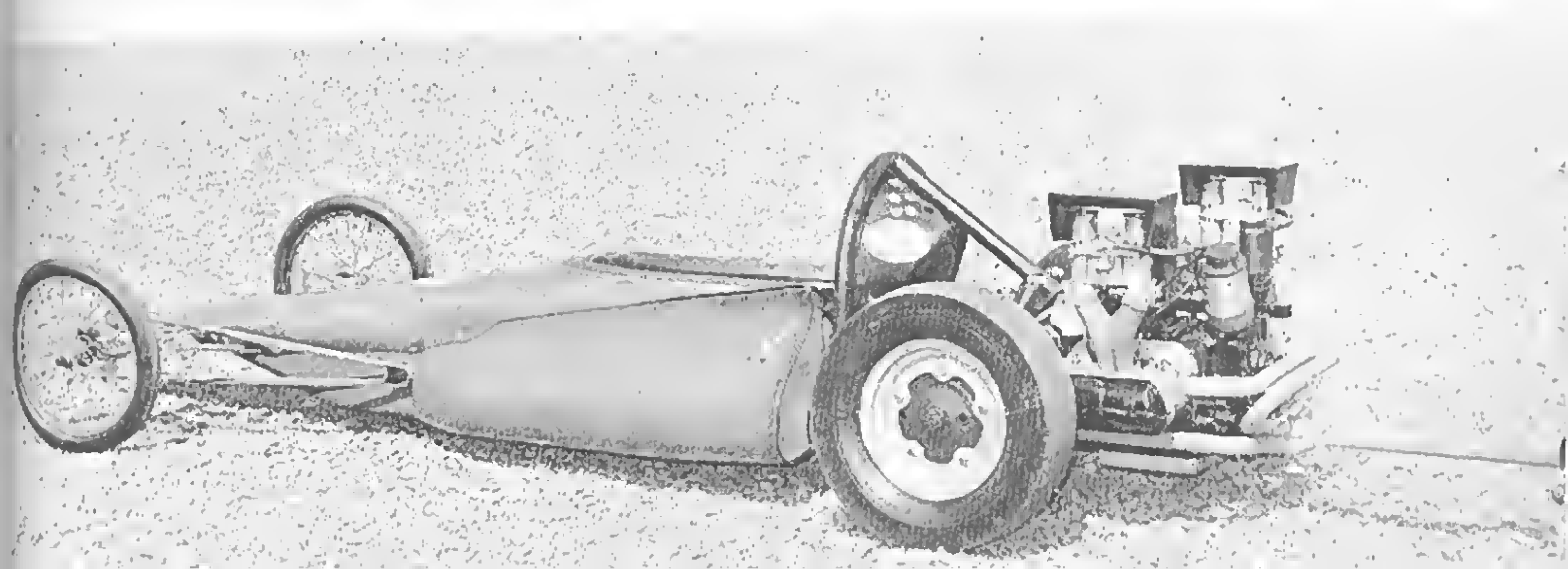
The split-case non-synchro-first transaxle uses identical mounts for the torsion arms, fork mounts and clutch cable, but its front nose mount differs from the later units. There are two ways to install the later transaxle into a 1960 or older chassis. The easiest is to buy from the VW store, scooping the following parts out of the 1960-67 bus parts bins: front transmission cover P/N 211 301 205H, gasket 211 302 215, shift rod 113 311 541 and transmission front mount pad 211 301 265 A. These bolt right into the early chassis. If yours is a '60 chassis, the mounting on the torsion tube has smaller bolts and the mount can be bushed to fit snugly with bushings from a transporter exhaust clamp/support, P/N 211 251 247. Don't try to get by with a sedan shift rod because it will not work correctly. Because the bus shift rod has its locator dimple or detent on the bottom, you'll have to drill a detent in the top of the shift rod to permit attaching the coupling from the chassis shift rod. An old coupler can be carefully set up in a drill press and drilled straight through from the original set-screw hole. Then attach the coupler to the bus shifter rod with the set screw and use a transfer punch in the new hole to locate a new detent in the top of the shift rod.

The second, but harder way to go is to use a new front mount P/N 111 701 073C on the torsion tube. Cut the old mount from the torsion tube with a torch. Position the new transaxle in the platform as it will normally be mounted. With the new mount in place on the nose of the transaxle, mark where the new mount should be on the back of the torsion tube. Remove the transaxle and weld the mount in place.

No novice should tear into a VW transaxle unless he is intelligent, has a VW service manual and access to tools such as a hydraulic press, because service to this component takes experience and some special tools not found in everyone's shade tree garage. A lot of Joe Greasythumbs can take one apart and put it back together—but the trick is to put it back with all clearances and pre-loading "on the money." This ensures long and trouble-free service. It's almost impossible to get a backyard-rebuilt transaxle to stay in gear because *the shift forks must be set in a jig!*

Details for "bullet-proofing" transaxles for off-road or other severe uses are in our book, "How to Prepare Dune Buggies and VW Sedans for Off-Road Use." It should be available from the store where you bought this book. You need a copy if you are planning to take your VW off-road.

Pull the Inch Pincher's engine and put it in the ex-Doug Church rail job for a 10.70 ET and 131 MPH at Carlsbad, California at one of the drags sponsored by *Der Kleiner Panzers.* Photos courtesy Petersen Publishing.



Converting flat engines to upright

consider *all* the costs before starting this project

How the names which are applied to the VW engines ever started, it is hard to imagine. For instance, the older style or "beetle" engines are called "upright" or "vertical-fan" engines, even though the blower on the end of the generator shaft runs in a horizontal plane parallel with the crankshaft. Flat-fan engines don't have a flat fan—the engine just "looks flat" because the fan bolts right onto the back end of the crankshaft. It operates in the same plane as the other style.

Changing one of the "flat fans" to an upright engine is sometimes helpful, especially when the late engine is to be installed in a beetle, bus or a dune buggy because the engine instantly shrinks in overall length when the crank-mounted fan is removed and the sheet-metal housings are changed for the upright style. All of the stock sheet metal from an upright engine will fit right onto the flat engine, as will the vertical cooler, crank pulley and nut, generator mount and so forth.

There are two items which must be changed when making the conversion. The first is the oil-pressure takeoff which is on the oil-cooler mount in the "flat" version. You lose this point of pressure indication because you switch the flat laydown cooler for the upright cooler—unless you are switching to an external oil cooler, in which case you can easily tap the external cooler hose adapter for the sender or pressure takeoff. Drill and tap the main oil gallery at the point where the sender would ordinarily be on an upright engine case for 1/8-inch NPT so that the stock pressure switch can be screwed in, thereby retaining a functioning idiot light to show that your oil pressure has gone South. Another slick-trick suggestion from Gene Berg is having someone crank the engine over with a starter to get oil pressure up as you drill into the oil gallery—cleaning out all of the shavings right up to the point where the drill breaks through. Then the pressurized oil in the engine will gush out to flush out those last few shavings which might be carried into the oil gallery as the drill breaks through. Coat the tap with grease and you can successfully tap the hole without losing any of the shavings created by cutting the threads. When you're finished you can install the stock sender or a tee with the sender in one side and an oil pressure sender or takeoff in the other side.

Second is a means of closing the oil-filler tube and measuring the amount of oil in the crankcase. This modification is also required when using a flat-fan engine in a dune buggy. The stock Variant cap and dipstick assembly screws into a part which stays with the body when the engine is pulled out. Get these parts from the wreck when you buy the engine and you'll save $4. What you need is a new dipstick 311 114 605A and that sleeve which normally attaches to the Variant body, 311 813 313. Because the sleeve is about four inches too long, cut through the part at the point where the tubing is welded to the part that accepts the cap/dipstick. Stretch the filler neck with a ball-peen hammer to allow the two parts to fit together—then braze away.

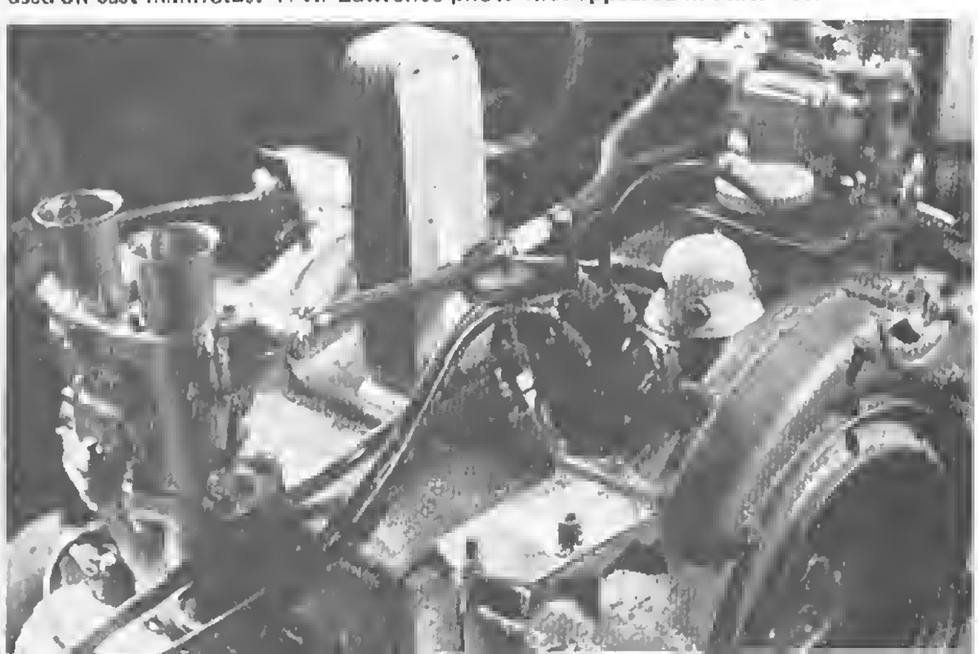
Cut a section out of the dipstick so that the dipstick will bottom against the bottom of the filler tube when the cap is screwed on, and then braze or weld the dipstick into a single piece. The flange around the filler neck can be either cut off or left for attachment of a brace.

With the availability of parts from the 1971 upright engine, it would be a good idea to use the cooler that came with your flat engine, mounting it on a 1971 cooler adapter to make it stand upright—and allow it to be used with the 1971 fan housing which has a separate opening for the cooler so that the left-side cylinders get their full share of cooling. Note, however, that a larger fan is used with the '71 housing and it is designed for use with dual-port heads.

If you are building the engine for competition and will not be requiring the fresh-air heating system, consider using a 36 HP fan housing because it has no openings to be closed off, making a heater installation. However, you'll want to use an external cooler so that the left-side cylinders won't be under-cooled.

The conversion requires a lot of parts, so unless you have an upright engine that can be cannibalized, prepare your wallet for a shock. By the time you have bought another generator, all new tinwear (and you don't want to leave off any sheet-metal parts), crank and generator pulleys, generator tower, fan, another oil cooler and the parts for the oil filler assembly—you'd better have a sack full of dollar bills to trade for the box of parts that the VW counterman hands to you.

Ed Zink Super Vee engine retains crank-mounted fan, uses fiberglas cooling shroud because competition cooler (not shown) lives in front of race car. 35 DCNL Webers used on cast manifolds. T. R. Lawrence photo first appeared in Autoweek in 1970.



Corvair power

cubic inches are cheaper than rectangular $$$

Crown's complete adapter kit has everything you need to install a Corvair engine into a VW or Porsche chassis. Late model VW's with the four-joint rear suspension must be equipped with a reverse rotation Corvair engine. Crown supplies a cam which does the engine reversal very simply. Swing-axle VW's require flopping the ring gear to the other side of the case to work with the stock Corvair engine, which turns backwards to the VW.

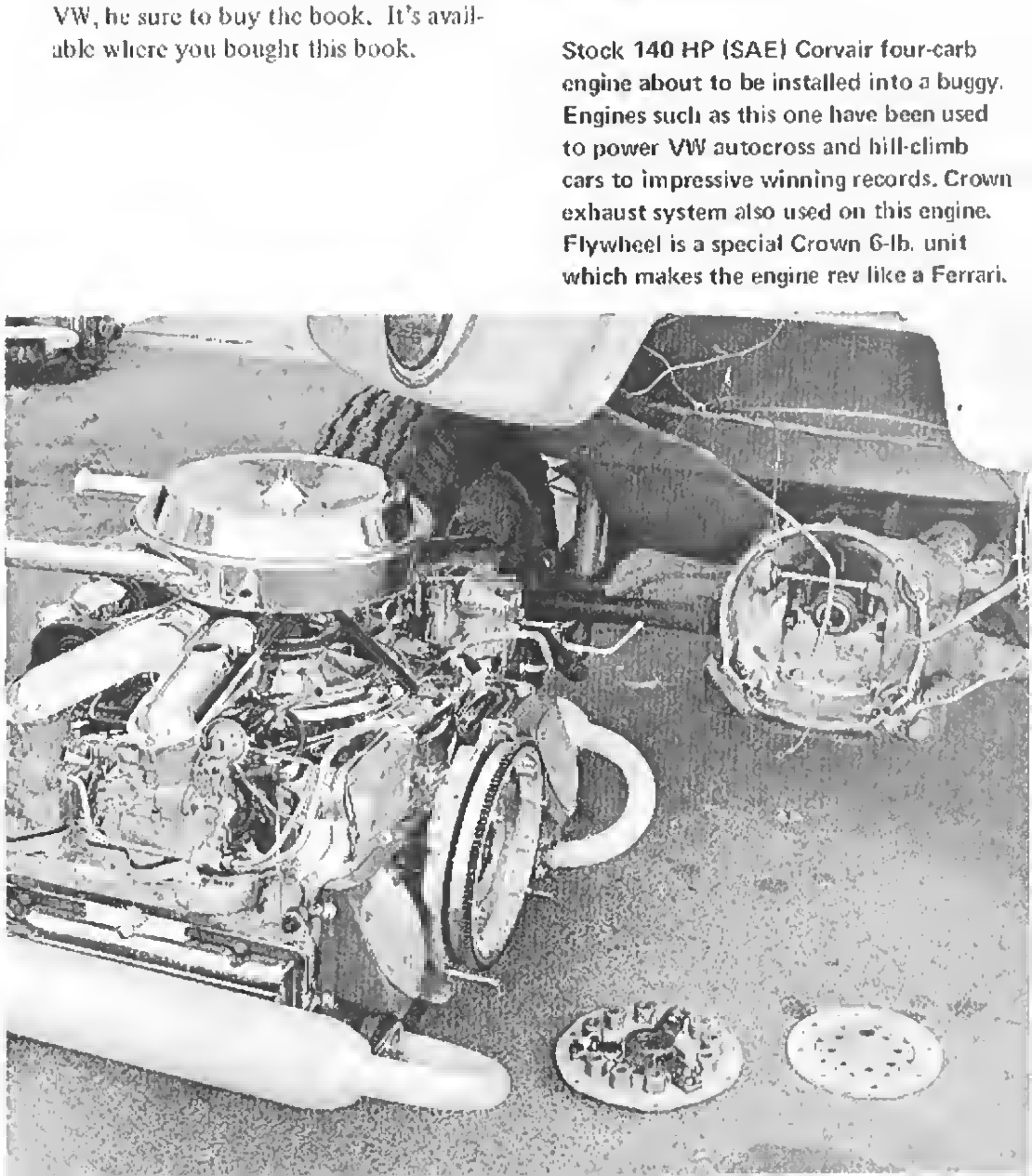
CORVAIR POWER?

Want more beans for your VW? I know the feeling because I've owned them, too. Even the owners of expensive Carrera and 911 Porsches admit that their cars' performances hardly equal that of U.S.-built machines costing half as much. General Motors has come to the rescue of every VW owner who has had his stomach, heart and wallet turned inside out by the parts and labor costs required for major performance modifications. With the introduction of the Corvair in 1959, GM unwittingly provided *power* for those who wanted it.

In 1962, my own 1961 Porsche Super 90 roadster was not providing the kind of exciting performance which I'd expected in the acceleration department. So, I bought a set of the first Corvair/VW conversion parts which were made available on the West Coast. The fine parts which are now available from Crown Manufacturing Co. make those early parts look like junk by comparison. Even so, junky makeshift conversion parts are still being sold today, so be sure that you know what you are buying or you will be in for real headaches instead of fun and games. In making the Corvair installation, I ran into all sorts of misinformation, traps, swindles and pitfalls related to reworking the engine and making the conversion.

As a result, and to protect others who might be planning to do something similar, I wrote my book, "How to Hotrod Corvair Engines." If you want to learn all about the Corvair or find out what to do to install one in your VW, be sure to buy the book. It's available where you bought this book.

Stock 140 HP (SAE) Corvair four-carb engine about to be installed into a buggy. Engines such as this one have been used to power VW autocross and hill-climb cars to impressive winning records. Crown exhaust system also used on this engine. Flywheel is a special Crown 6-lb. unit which makes the engine rev like a Ferrari.



Stability & the Beetle

Some of the speeds being attained by stock steel or fiberglass-bodied VW's at drag races, at Bonneville—and on the highway—are so far beyond the car's design speed that the drivers must be classified as both fearless and foolhardy. As I wrote this book and worked with some of the experts who are making the VW travel far faster than was ever intended, I came to the conclusion that it was extremely important for every reader of this book to understand that improved acceleration up to 75 or 80 miles per hour makes the VW a lot more fun to drive—but this kind of performance will let you push the VW into high-speed regions which are literally unsafe, especially on uneven road surfaces and/or in cross winds.

In the period from 1968 through 1970, a number of high-speed VW's were demolished on the drag strips as the speeds approached 120 mph at the end of a standing-start quarter mile—and 130 at Bonneville. It's hard to ascertain exactly what is happening, but photos have shown VW's "pawing the air" with their front wheels as they leave the dragstrip starting line. If the front lifts enough for air to push on the underside, flip-over may be inevitable . . . regardless of whether it's caused by a torque reaction or the car "flying" or both.

Paul Lamar tapes on giant rear spoiler as John Thawley, Hotrod Magazine's Technical Editor, assists.

I knew that the engine-building details contained in this book would allow a lot of VW owners to push their sedans to the same kind of drag race and top speeds. In hopes that some dramatic improvements could be made with one or more of the aerodynamic devices being sold for the VW, I contacted the world-famous aerodynamicist Paul Lamar of Manhattan Beach, California. You've probably read his outstanding articles on aerodynamics in Road and Track, Car Life, Sports Car Graphic and in publications of the American Institute of Aeronautics and Astronautics. So, you say, what kind of Detroit Iron does this guy Lamar drive? Would you believe that his transportation is a VW squareback—and his wife's a Ghia VW? To add to his credentials, let's just say that Paul Lamar consults regularly for the larger firms in Detroit—and was formerly aerodynamics engineer in residence at Midland, Texas for Jim Hall's early Chaparral race cars.

His first comments were that he did not think that there was anything which could be done to make any improvements, but he'd be willing to supervise and instrument a series of tests to measure the lift on the VW and to check some of the bolt-ons which are sold with fantastic claims of what they will do to improve VW stability.

We used a 1969 VW with the four-joint all-independent rear end suspension because it has better stability than the swing-axle models which were formerly produced. The improvements which can be made to a swing-axle are well known and fully discussed in this chapter. The improvement in the four-joint models is due to the suspension change because the body has the same aerodynamic problems which have plagued VW since its introduction to the U.S. in 1949. In fact, the stability of the late-model is so much better that we wondered whether anything could be done to improve the car from an aerodynamic standpoint because it was so obvious that the factory engineers had "really done their homework."

Giant wind machines rented from Ritter, the North Hollywood outfit that supplies such stuff to the movie and TV studios, were taken to Digitek's Riverside Test Facility. Lamar's lift-measuring instrumentation was installed in the car with a motor-drive Nikon camera. Another motor-drive Nikon with a telephoto lens was lined up with the course to record any deviation from a straight line caused by the cross wind.

We made run after run past the big wind machines, first in the stock configuration, then with a bolt-on fiberglas belly pan under the front bumper, with a bolt-on duct device under the front, with a giant spoiler on the roof, with a spoiler under the front—and even with a vertical tail hung behind the car on a tube framework. Look at the lift-data table. Note

Paul Lamar getting 1969 VW sedan ready for test runs. Cables attached to hub caps operate height recorder inside car.

Test instrumentation included Lamar's height recorder and motor-driven Nikon camera with wide-angle lens.

Bill Fisher, left, and Paul Lamar finish attaching tail made from one of Lamar's Formula B wings. Wind machines in background.

that the factory "tuned" the body lift by raising the front of the VW about 1.5 inches in 1966 so that the front lifts more than the rear as speed is increased. This helps to counteract the VW's oversteering tendencies caused by lift, the jacking effect on swing-axle models, and "bump steer"—even in the four-joint models. This should tell you that lowering the front of your VW is not a good idea because it reduces the lift on the front, thereby aggravating oversteering and increasing instability in cross winds and/or at high speeds. In fact, pre-1966 models should be raised in front so that they are at the same attitude as the late models, thereby improving stability. As you continue to peruse the figures, you'll note that anything which is done to the front affects the rear at the same time.

The conclusions which can be reached from this expensive and extensive investigation are as follows. First, and foremost, the VW engineers have done a fine job with the low-drag, large-volume (for its weight) body which they had to work with. The beetle lifts when wind is blown over it from any angle . . . front, rear, side, 45 degrees . . . every surface is rounded and every rounded surface creates lift. *None of the commercially available bolt-on devices or other items which we checked helped the VW's stability capabilities, with or without a cross wind.*

We just couldn't find the dramatic improvements which have been advertised and claimed for these devices. Perhaps the improvements are in the mind of the buyer. Psychologically, we all tend to invent reasons about why we made a purchase, even when the purchase turns out to be less than what we had hoped for.

Anything which could be done to improve the stability of the beetle body would drastically increase drag—and would require drastic redesign of the body steel to replace the rounded edges with sharp angles . . . and the top would have to be made concave instead of convex. When all things are considered, the bare facts are these: The VW is probably close to flying as it approaches 100 mph. *For your own safety and the safety of all others on the drag strip, highway or wherever, stick to speeds within the original design capabilities of the car—about 75 mph.* And, as a prudent driver should do with any kind of suspension, reduce your speed when you get into cross-wind or slick-pavement situations.

What has VW done about it? Well, their 411 body style is not an enlarged beetle—its squared-off body should be fairly stable from an aerodynamic point of view. Unfortunately, these cost a bit more than a beetle and you can be sure that VW's slow depreciation rate will keep the price of the used 411's 'way above that of a beetle. So, you'd better learn to live within the beetle's zone of reasonably safe performance.

Careful attention to other items which can improve stability, such as anti-sway bars, camber compensators, wider rims, wider tires, and better shock absorbers, is still needed—and all the more so on the swing-axle VW's, whether beetle, sedan, bus, truck, fastback or squareback . . . or even Ghias. Just because we failed to find any real way to improve the body aerodynamically does not mean that you should throw up your hands until you can afford a VW 411. You can make changes now—at reasonable cost—which will add to the stability of your car and you should not hesitate to do so. You'll certainly find that such changes greatly enhance the enjoyment of driving your bug.

How about that big vertical tail? Well, it was a head turner! Everyone who saw it had to find out what we were doing. It was tested to see whether a commonly held theory could be proven in practice. The theory states that the VW is so designed as to push its center of pressure ahead of its center of gravity, thereby causing instability which could only be corrected by hanging a tail way out behind the center of gravity. Conclusion: We couldn't find any difference with or without the tail, so the theory may not be a good one, at least when it's applied to the VW.

STABILITY & THE BEETLE

by Paul Lamar

This section was prepared by Paul Lamar in the hope that it would offset some of the more common misconceptions about the Volkswagen and what can happen to it when people drive it "beyond design limits."

In 1970 I undertook a research program in conjunction with Bill Fisher of H. P. Books on the cross-wind stability of a 1969 beetle. We found that the stability problems of the VW are due partly to suspension and partly to aerodynamics. Results are shown in the preceding material, but the problems of stability need to be better understood by all auto enthusiasts, hence these few paragraphs.

Aerodynamic problems increase as the car is extensively lightened for drag racing. For example, the total aerodynamic lift on a stock 1969 beetle is 430 lbs. at 120 mph or about 24% of the total stock weight of 1800 lbs. However, if you lighten the car to approximately 1000 lbs. (for drag racing), then this 430 lbs. changes to 43% of the total weight of the car. If you suddenly encounter a head-wind gust of 20 mph while traveling at 120 mph, the lift radically jumps to approximately 60% of the weight—definitely in the dangerous category. If you are unfortunate enough to get side-ways at 120 mph, the lift will double or triple because then the bug becomes a much better wing, takes off, snap rolls and it's all over except for the screech of metal on pavement and the tinkle of broken glass.

In the stock VW, the rake angle of the body is such that the lift is evenly distributed front and rear. If you increase the rake of the VW body (by lowering the front or raising the rear suspension), you will reduce lift on the front end of the VW and will soon encounter stability problems at speeds much less than 120 mph. The reason for this is that the car tends to pivot in the area of its front wheels, and thus tries to swap ends.

What is needed is an overall reduction of lift or even aerodynamic downforce distributed in such a way that the car pivots about the rear wheels a much more stable condition. This means more lift or less downforce on the nose that on the tail. However, you should not insist on performing wheelies through the lights. If you do, the car will flip over backwards due to the greatly increased aerodynamic nose lift. Reducing the aerodynamic lift at the rear of the car with a roof spoiler, cooling scoop, or large wing mounted far enough above the body in unobstructed airflow will do the most amount of good. Removing the rear windows and venting the top and rear of all the fenders with louvers will also reduce the overall lift. All these modifications should be carefully checked with a device that measures suspension movements while the car is traveling at a constant speed. The VW Beetle's voluptuous lines intensify the aerodynamic problem. If a new VW with a "more boxlike" shape were developed, the current lift problems would be greatly reduced.

Much has been said and written about the rear-engined car being unstable because the car's center of gravity is behind its aerodynamic center of pressure. Well, it's just not true. The other factors that affect overall stability are more favorable with a rear engine. Among these are traction advantages while cornering, accelerating and braking. One surprising point is that rear-wheel-drive, rear-weight-bias cars are actually more stable in high speed corners than front-weight-bias cars (all other things being equal). This is because the traction that causes the car to go forward is subtracted from that used to hold the car on the curve and there is more total traction available at the rear with a rear engine. Therefore, there is less tendency for the car to spin out. This characteristic is seldom noticed on passenger cars because it is usually overshadowed by excessive aerodynamic nose lift. However, the total high-speed cornering power is much reduced. This traction effect in high-speed corners is one of the main reasons all road-racing cars are mid- or rear-engined, with weight biased to the rear.

In my opinion, one of the reasons rear-engine cars have acquired a bad name (for the wrong reason)

Lamar prepares to start a run with the stabilizing tail—which was of no particular assistance to the handling. Giant wind machines from a Hollywood studio were turned on to create a 60 mph gale side wind. Bob Loring/Skelton Photography photo.

Bill Fisher mounting front spoiler for tests.

with various people is that most of these cars have had a swing-axle rear suspension of one type or another. This list includes VW, Corvair, Renault, Fiat, Porsche, Simca, Triumph, Mercedes and NSU. A point frequently overlooked by engineers while designing a swing-axle suspension is the self-energizing characteristic of swing axles. The disadvantage of this is that the weight transfer from inside wheel to outside wheel while cornering is proportional to the height of the center of gravity, and the "jacking" effect is proportional to the weight transfer. The "jacking" effect is exactly that. It raises the car body on its suspension and therefore the center of gravity, which in turn increases the weight transfer. The automobile body continues to jack or rise from the ground. One split second later the car spins out, if not rolling over, because its rear tires, due to the swing axle, go into unfavorable positive camber. Needless to say, a disastrous result.

A phenomenon termed "bump steer" will compound the situation if it occurs. "Bump-steer" is a change in toe-in or toe-out as the wheel travels over a bump, drops into a dip or jacks itself down in a corner. Guess what! Swing-axle and double-jointed (four-joint) VWs, as well as most other cars with swing axles, have bump steer in large amounts. Bump steer also does exactly what it says it does—it steers the car. It may tell the car to turn left when you tell it to go straight. "Toe-in" is not as bad as "toe-out" when traveling over a bump. For example, let's say you turn the car left. The resultant force on the outside rear wheel causes it to rise up into the fender—just as if it had encountered a bump. If the tire "toes-out" at the same time, that would tend to increase the angle of the left turn. This is technically known as "roll oversteer." It has a de-stabilizing effect which the driver can correct by immediately decreasing the steering-wheel angle of his car. However, it is a very uncomfortable feeling. If the outside rear wheel "toes in," then the magnitude of the turn will merely be reduced and will not be noticed by the driver as anything except a slight delay in steering responsiveness.

If your VW has positive camber while traveling down a road at speed, it will "toe-out" on bumps and "toe-in" on dips. The reason for this is the peculiar swing-axle trailing-arm geometry forces the suspension to rotate around an axis approximately 45 degrees off the car center line. Because of this, camber, toe change and suspension—up and down motion—are intimately connected. You will notice I said while traveling down the road *at speed*. The car may have negative camber while sitting in your driveway, but positive camber at speed due to aerodynamic lift and traction-bar lifting effect from the trailing arms.

You can check the toe change on your car by rigging a long piece of string parallel to the center line of the car just a few inches from the wheel rims at a height equal to the wheel center. Measuring the distance from this string to the front and rear of the wheel rims while depressing the suspension springs by placing additional weight on the car will detect any toe change. Better racing-car designs have less than 0.010" toe change over the full up-and-down movement of their suspension.

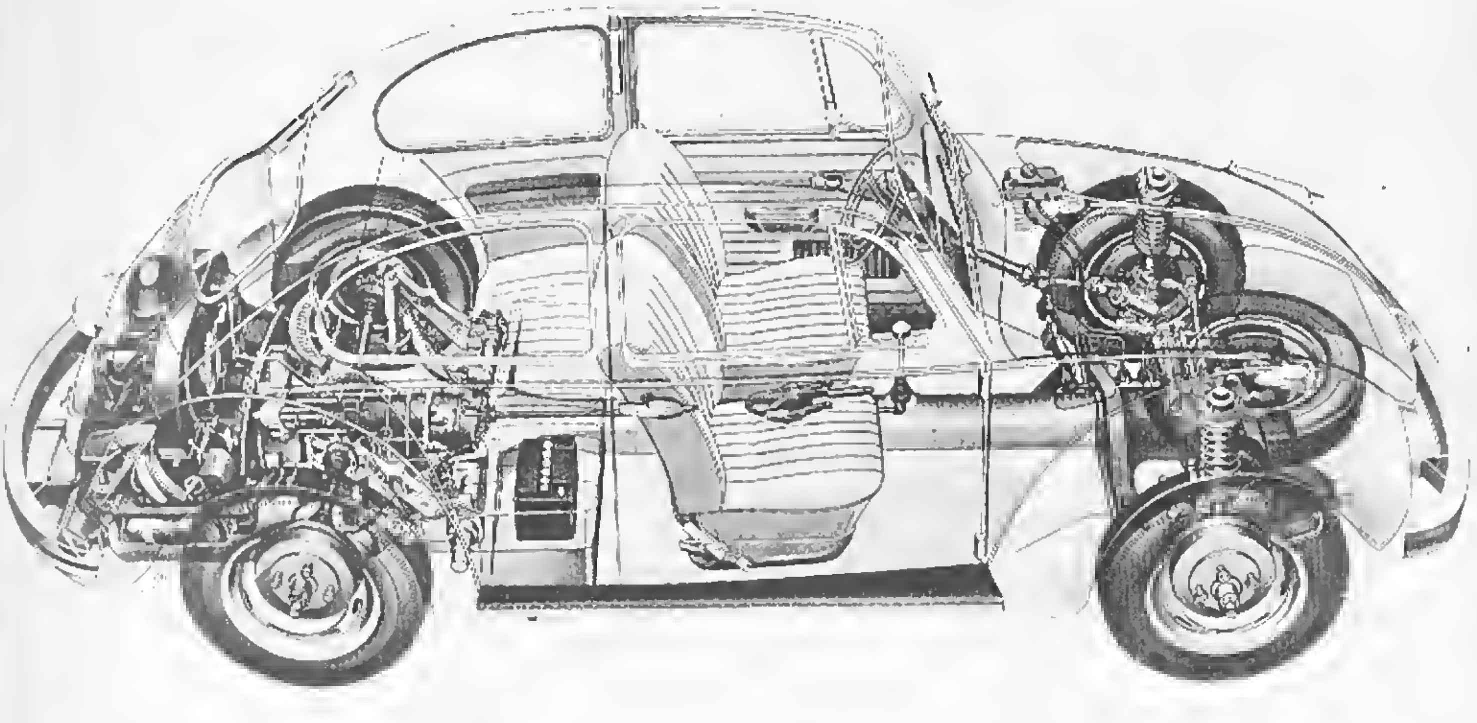
Very little can be done about the basic geometry problem of the swing-axle VW without drastic, extensive surgery to the rear suspension. What *can* be done is to reduce the weight transfer at the rear by installing a large-diameter front sway bar, and by using a compensating spring in conjunction with smaller torsion bars at the rear, thereby forcing the front suspension to assume more of the total weight transfer. *Do not omit the front sway bar no matter what type of front suspension is used because it is absolutely essential for stability.* Mechanically limiting the rebound travel of the rear suspension to zero camber with rebound straps or stops or running excessive static negative camber is not a particularly good idea as this approach often develops suspension harshness and breakage. One other idea that might help ease the same problem is to check the rear-wheel alignment to insure static toe-in. This is adjusted on the VW with existing slotted holes in the trailing arms. Group 7 cars run up to 3/8-inch total toe-in at the rear. This 3/8-inch toe-in, however, remains constant throughout the total suspension travel, unlike the swing-axle VW.

The moral of this story is that the aerodynamics of the beetle and its suspension are interrelated. Any change in one will affect the other and vice versa. Hopefully, this article has given the concerned VW driver food for thought and a few new ideas toward preventing those puzzling, crunched bodies—both human and bug.

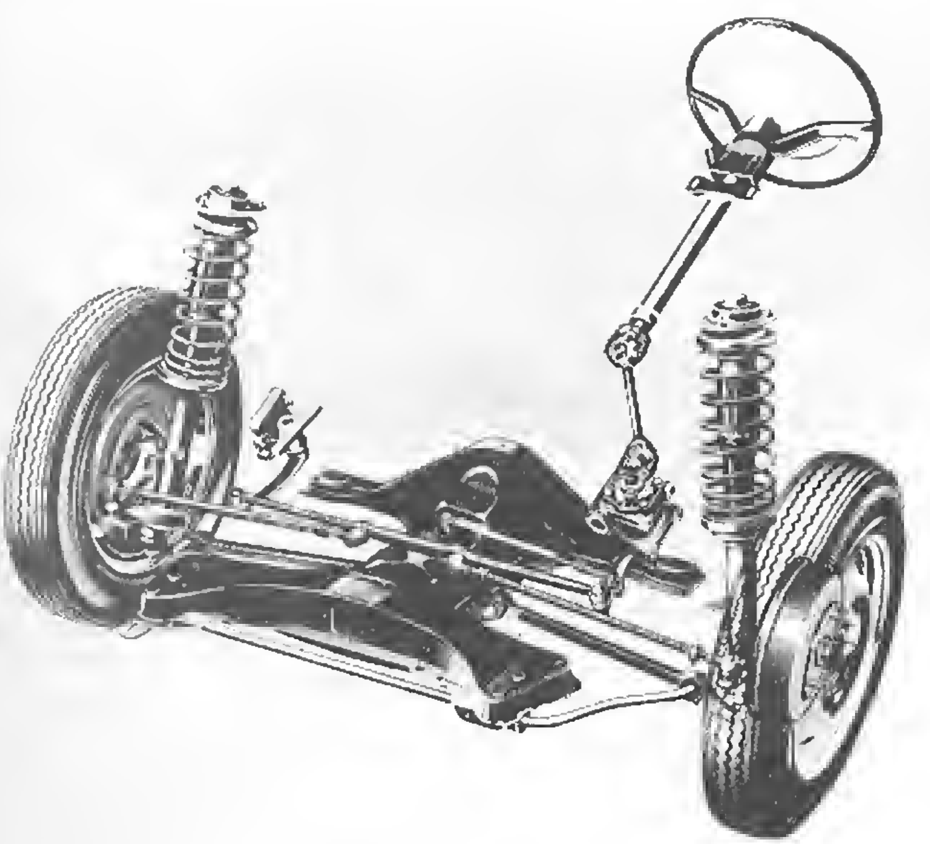
Lift Data
1969 VW "Beetle"

Configuration	Speed (mph)	Front Lift (lbs.)	Rear Lift (lbs.)
Stock	75	76.5	68.0
	100	153.0	136.0
Bellypan at front	75	47.0	67.0
	100	94.0	134.0
Hermes AeroFoil	75	80.0	78.0
	100	160.0	152.0
4" lip spoiler at front	75	39.5	78.0
	100	79.0	156.0

Note: 100 mph lift figures extrapolated from lift at 75 mph figures.



1971 Super Beetle, showing MacPherson-strut front suspension and 4-joint rear suspension. Drawings courtesy Volkswagen of America, Inc.



Handling

simple changes make a big difference

Improving VW handling gives you more fun from your everyday driving! Handling improvements will give you more constant pleasure than any amount of engine modification. This section should probably precede the engine-improvement sections because it is more important to most VW owners. Pre-1969 swing-axle VW's (especially) respond eagerly when you bestow tender loving care and attention on their suspensions. There's a "night-and-day" difference between a stock VW and one with a few minor suspension/brake/tire modifications. You won't recognize it as the same car, but you'll find that driving suddenly becomes what you had always hoped for. If you are competition-minded, then these changes will increase your trophy-winning potential. The 1969-70 VW's (four-joint fully independent rear suspension), although great handling cars straight off the showroom floor, can also be enormously improved for more driving fun.

A VW with modified-suspension rides like an MGB or a Porsche. Not as hard or stiff as the MGA or TD, Triumph TR-3 or TR-4, Jaguar XK-120, or Sprite—and not so soft as a 190-SL Mercedes, Jaguar XKE, or a Corvette Stingray. It's stiff enough so that you know that the car will do what you ask of it. Your wife or girl-friend may not like it.

Much has been written about improving VW handling. Many of the articles were written to sell a certain product. It has often been hard to determine where actuality was overshadowed by enthusiasm and sprinkled with misunderstandings as to what was actually occurring on the "road test." In getting detailed information to be able to write this section, I am most fortunate to be living at the center of autocross competition (slalom, for you who live east of the Rockies!)—Northern California. The area has long been 'way ahead of the rest of the United States as regards general widespread knowledge and understanding of setting up cars to handle over these tricky courses. I am referring to a general understanding by the competitors and not knowledge in the minds of a few gifted souls. Even Southern California usually takes a back seat to these invaders from the San Francisco-Oakland Bay Area, as proved regularly in the North vs. South Competitions held each July 4th in Santa Maria, California. The situation is assisted by several very active clubs which post impressive year-round autocross calendars.

Some competitors run two or even three events on a single weekend! This hotbed has spawned many formidable Volkswagen pilots.

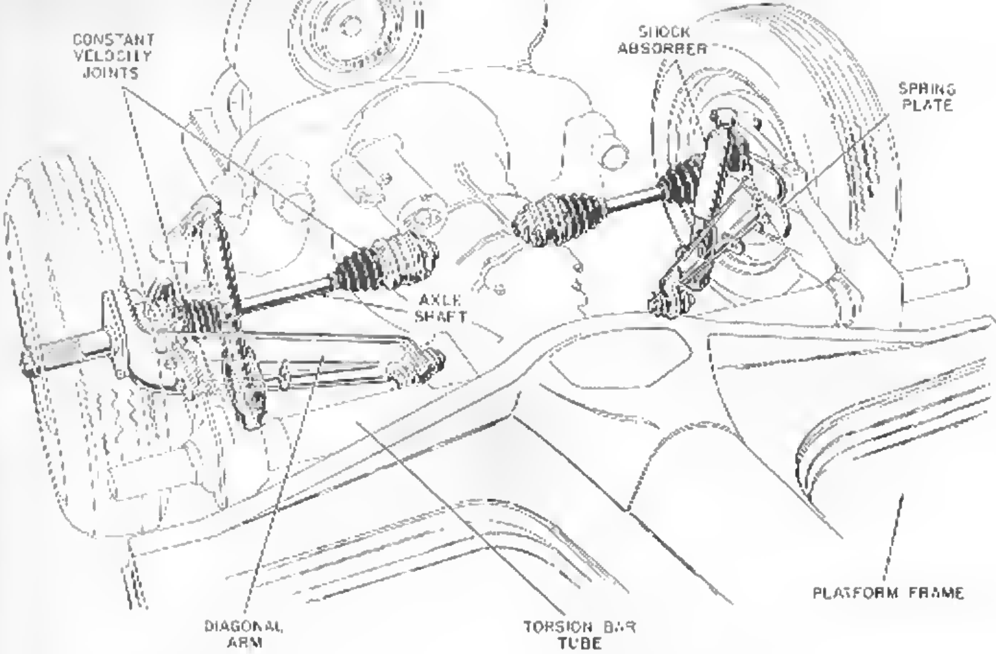
Northern California rules may be different from those used in other parts of the country, as cars are classed according to their competition potential. Instead of just running against other sedans, the VW's must compete with all production sedans over 1450 cc in either stock or "prodified" classes.

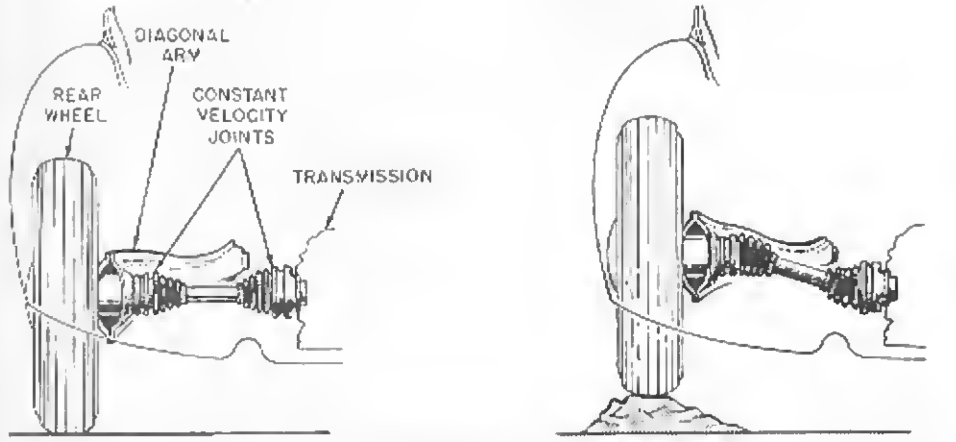
Four drivers were extremely helpful in providing details for this section and for the three-stage chassis-tuning table. One was Joe Reitmeir of Reitmeir's Werkstatt in Los Altos, California. His 1963 VW sedan was a top runner for several years in a row. Karl Barnett, whose car is described in detail, was also a big help. And, two old friends, Glen Fotre and Erick Ressler, helped with details of how they made their winning VW sedan "Rumplesteelskin" behave on the autocross courses. This fabulous Corvair-powered, Crown-equipped VW sedan was the scourge of everything—including racing Cobras—during the 1965-66 seasons. With guidance from these men who spent their own cash for equipment and tires, truth and fiction were soon separated.

"Acceptable" riding and handling qualities mean totally different things to a driver, depending on his/her past experiences. In general, when I talk about making a VW "handle better," I mean making its response more predictable. Through changing various items, the owner can make the car understeer or oversteer at will, and he can build "feel" into the car so that he can predict what will happen ahead of time. In a "handling" VW the driver feels as if he belongs to the car and is riding with it—rather than sitting on it and operating the controls as if on a skateboard! Autocrosses and slaloms, at least in the U.S., are run on billiard-table-flat surfaces such as parking lots, airfields and the like ...so what it takes to make a winning autocross car greatly differs from what you'd

Hermes Aerofoil was just one of the zero-improvement devices we tested. We could have gotten the same results by taping the box under the car—for less $$$.

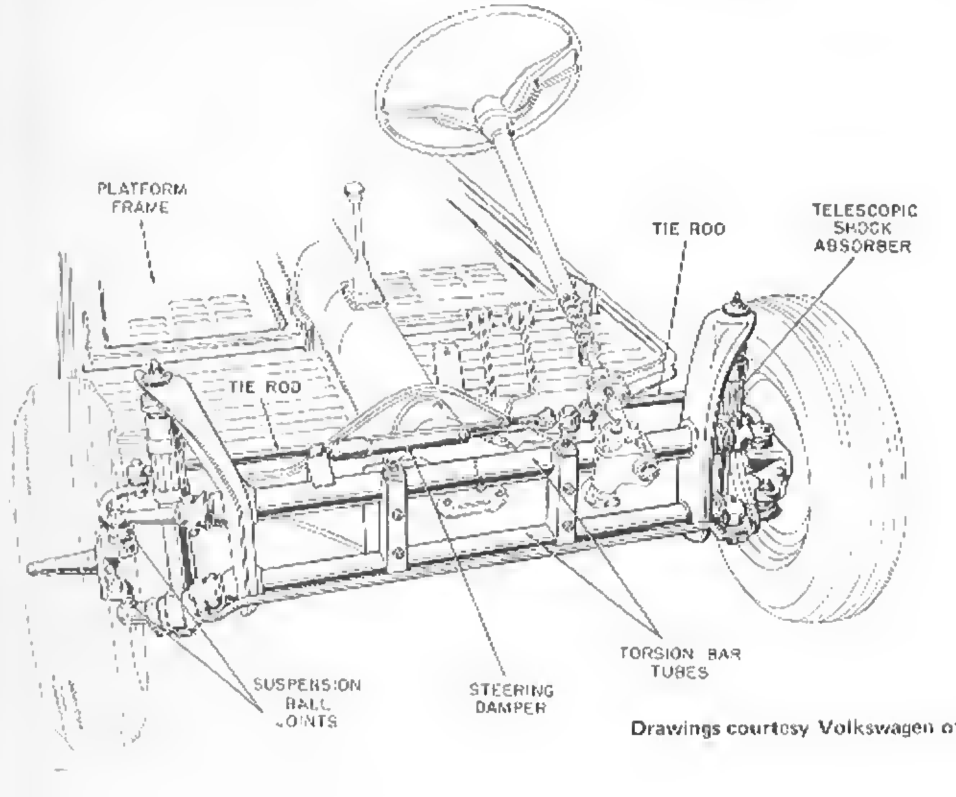
This fiberglas bolt-on "spoiler" did not improve handling, stability, or performance. All it spoiled was a twenty and and a ten.





Underside view of four-joint rear suspension used on 68 and later busses. Combination of trailing arms with diagonal links tends to keep wheels vertical as they move up and down. Bug and Type 3 rear suspension is same on 1968 auto-stick-shift and on all 1969-71 model VW's.

Front suspension of VW's has ball-joints for spindle support from 1966 through 1971 models. 1971 Super Beetles have MacPherson front suspension. Pre-1966's had link-pin suspension on front.



Drawings courtesy Volkswagen of America, Inc.

find "acceptable" in a street or road car. Autocrossing is a "weird" form of automotive competition with peculiar requirements. It literally demands a car which is unstable so that it can be provoked to do what the driver wants it to do. For this reason, the Suspension Tuning Table is not specifically designed for the autocrosser, except as noted.

Too bad that more VW owners cannot read what's needed before jumping to the conclusion that the VW's a sports car. You know—like a Porsche! The rear engine does not make the car a Porsche, much less a grand-prix racer! The wheelbase, high roll center at the rear, high center of gravity, and swing axle (pre-1969's) all contribute to handling problems which are not helped by the ineffective shock absorbers, flexible soft suspension, narrow tires and skinny rims. Enthusiastic and/or careless drivers soon find themselves bargaining with the fender and roof benders to repair spin-out or rollover damage.

The 1969 and later VW's fully-independent "four-joint" suspension is "something else" in any book. However, many of the same improvements which are recommended for the pre-69's will work on the four-jointers because good handling requires similar modifications, regardless of the automobile. I'll also say again that the modifications will stiffen the suspension so that you will feel even minor bumps on the road. But, ride smoothness depends on car speed and the road surface, and you will be having so much fun with your transformed car that the bump magnification will be forgotten as soon as you grow calluses in the desired locations.

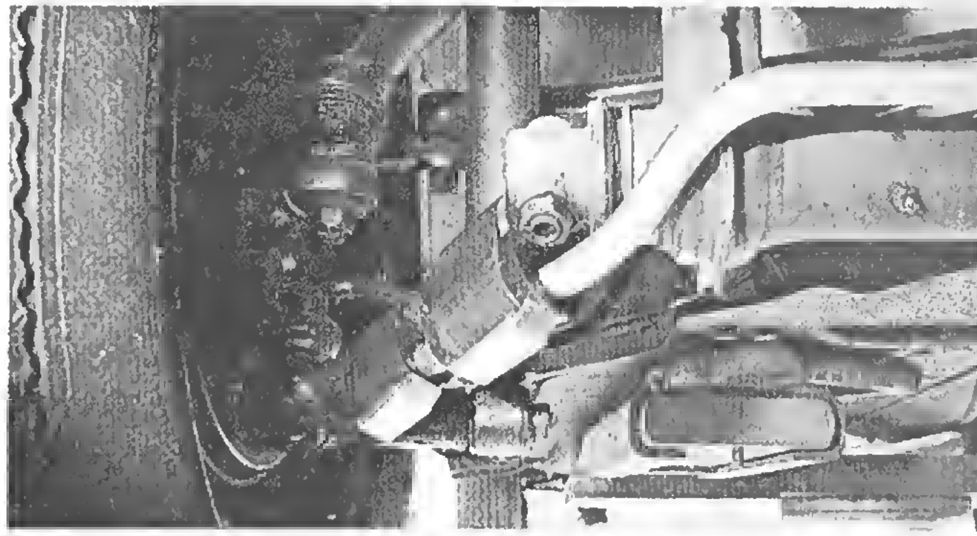
As in improving an engine, suspension and handling changes cost time and money. You can choose the degree of improvement which you require, working up to the various stages as you find your driving becoming that much more enjoyable. The parts which are needed are readily available. The Handling Table should be very helpful to you as you set about to make your VW handle like a true sports car. The All-Out version, especially with a limited-slip differential, is an exciting and completely predictable car. Understeering or oversteering can be selected to fit everyday needs by simply

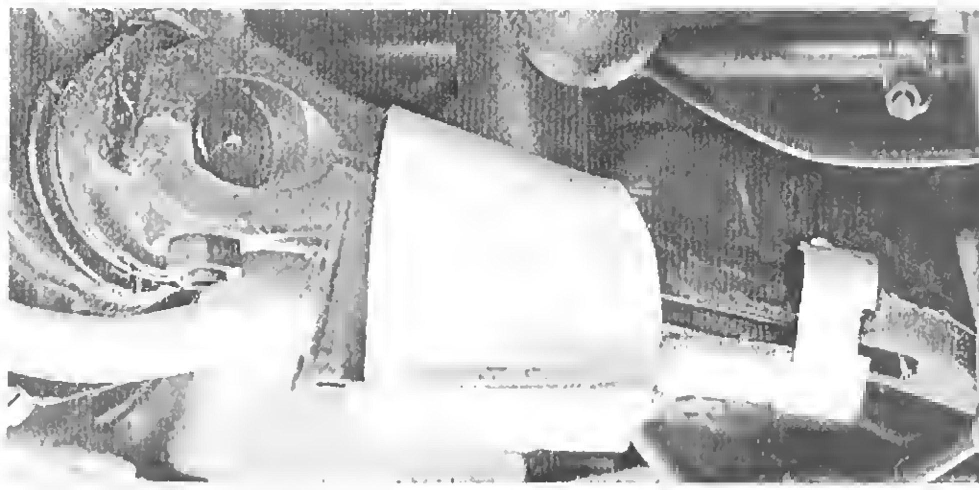
changing the rear toe-in. More toe-in moves the characteristics toward the understeer condition, which can be augmented by increasing the stiffness of the front anti-roll bar. Less toe-in tends to make the car oversteer.

Steering characteristics, contrary to what you might hear from the bench-race crowd, are not so much influenced by the rearward weight bias as you might guess. In general, slow tight corners are negotiated quickest with an oversteering car—that is, one with reduced rear-wheel adhesion. Faster courses require understeer for the quickest times. An oversteering car, unless the driver has had a great amount of experience, will be too quick to spin as cornering speeds are increased. Also bear in mind that when you "lose" the VW in a corner, there is little chance of recovering from the spin, regardless of suspension modifications. Here is where the rear weight bias tends to work against your best efforts. But don't be discouraged—your VW can get around short, tight autocross courses just as fast as the 83-inch Porsche, 90-inch Cobra, or 98-inch Stingray Corvette. Faster cars will nearly always be overpowered dune buggies, Corvair-powered VW's, Mini-Coopers, or other special vehicles. Longer, high-speed courses become a problem because these require brute horsepower. Today's top autocross runners are mid-engined, short wheel base, full-independent-suspension (not swing axle) specials. Such a combination is almost impossible to beat with a stock-based automobile, regardless of what modifications you may make to the chassis or engine.

ANTI-ROLL BARS (STABILIZER OR SWAY BAR)

It has long been understood by chassis builders that fixing a torsion bar across the chassis and coupling the ends through links to the suspension members resists cornering roll or lean without affecting up-and-down movements over normal bumps. This torsion bar must be fixed to a very rigid portion of the chassis, but left free to rotate in its bearings. If the opposing wheels are raised and lowered in unison, the anti-roll bar has no effect. Raising only one wheel twists the torsion bar and its natural springiness resists the twisting movement. As the car leans in a corner, the effect is to raise the outer wheel and lower the inner, and this movement is resisted by the bar, transferring weight to the outer wheel.





Top: Front bar installed on beetle, showing EMPI mounting hardware which is supplied with the kit. Bottom: Same maker's bar mounting for a Type 3 (fastback, squareback).

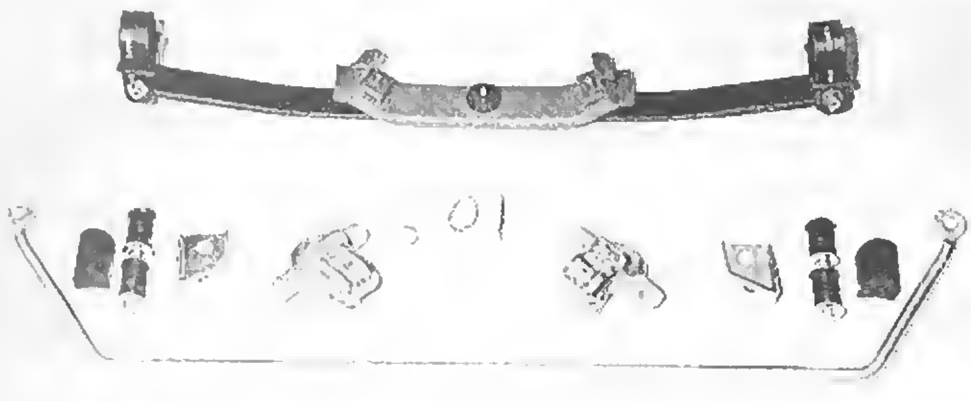
A front anti-roll bar adds understeering characteristics at the front of the car. The stiffer the bar, the more weight transfer, and the more the outside front wheel will "wash-out" or "plow". There is also a diagonal couple from the outside front wheel to the inside rear wheel so the anti-roll bar also aids in keeping the inside rear wheel on the ground—which is helpful regardless of whether or not you have a limited-slip differential.

Front anti-roll bars were first introduced for VW's by the factory, on the Ghias in 1956. Sharp VW owners quickly bolted these onto their sedan VW's. Serious drivers found the stock bars too small for the type of control which was needed, so two stock bars were often used, clamping them together. Then EMPI made the 3/4-inch heavy-duty bars available and ADDCO subsequently introduced a 3/4-inch front sway bar.

Paul Lamar takes a firm stand on the need for anti-roll bars and camber compensators in his discussion of Stability and the Beetle in the Stability chapter. Tests made by Scott Laboratories for EMPI in 1964 showed that the use of these components decreased body top tip up to 9% in 30 to 40 mph turns due to a roll-stiffness increase of up to 23%. For each of the constant-radius turns checked, the modified suspension could go at least 5 mph faster without the rear wheels breaking away.

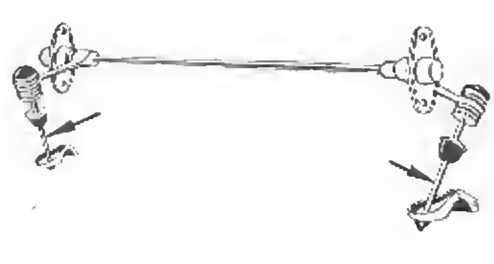
RACING ANTI-ROLL BAR (front)

Forge Enterprises of Palo Alto, California makes a 5/8-inch-diameter front anti-roll bar which is adjustable for rate. Although the bar is twice as expensive any other



Two EMPI rear bars. At the top is Camber Compensator which fits all Type 1, 2, and 3 VW's through 1968 non-automatics. Below that is anti-roll bar used for Type 1 1968 stick-auto and all 1969-71's.

CAR	MFGR.	FRONT DIAMETER (IN.)	REAR DIAMETER (IN.)	COMMENTS
BEETLE				
Type I Sedans & Ghias	ADDCO	3/4	3/4 & 7/8	1966-71, except Super Beetle. Front and rear should adapt easily to 60-65 models. Front uses stock VW sway-bar mount hardware.
	EMPI	5/8	Camber-Compensator Bar for swing axle, 5/8 anti-roll bar for 4-joint	Units available for all VW's 60-71, including Super Beetles.
FASTBACK, SQUAREBACK				
Type III	EMPI	5/8 & 3/4	Camber-Compensator Bar for '68 and earlier, except '68 automatics.	
BUSSES (Transporter)				
Type II	EMPI	none avail.	Camber-Compensator Bar for '68 and earlier, except '68 automatics	



VW factory-installed Z-bar needs spacers to make it work full time as a camber compensator at points shown (arrows). These bars are used on swing-axle-equipped 1967-68 beetles and Type 3's.

on the market, it was designed by a successful VW/Porsche competitor. He applied his mechanical-engineering knowledge to solve the problem of being able to adjust chassis characteristics to a race course in a matter of two or three minutes. This bar can be adjusted from maximum understeer to very little understeer by sliding the mounting blocks in or out on the lower torsion-bar tube. The bar, with its adjustable mounts, is supplied in a $50 kit which includes new lower link pins which provide mountings for the bar ends. The kit fits all link-pin-type VW sedans and Ghias (Type I) but will not fit ball-joint front ends.

CAMBER COMPENSATORS & Z-BARS (rear)

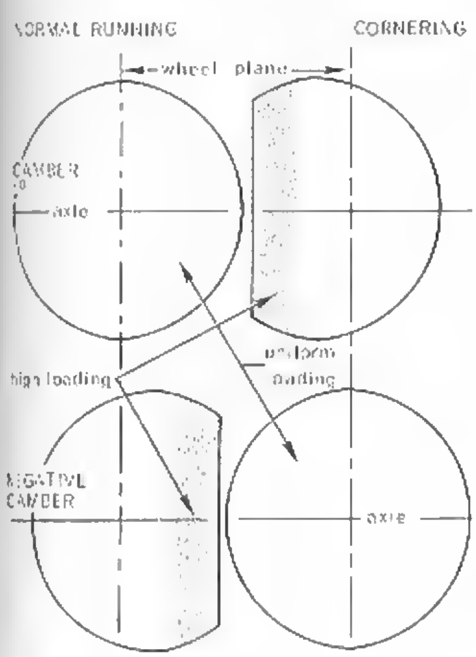
Camber compensators work exactly oppositely to an anti-roll bar in that they hold the inside rear wheel on the ground and help to prevent the outside rear wheel from proceeding too fast and too far towards positive camber. It helps the swing axle to resist its built-in jacking tendency. A camber compensator should be installed on every swing-axle-equipped VW. In fact, the factory has already put one on your VW if it is a 1967 or later beetle (swing axle) or a Type III fastback/squareback with swing axle. The factory device, known as a Z-bar, is used with smaller torsion bars so that the Z-bar also acts as an overload spring when the car squats in back when heavily loaded. Because it is used with softer springing, rear roll stiffness is reduced and oversteer is less on models thus equipped. However, the stock setup does not work full-time and has a disconcerting time delay built in because the suspension has to move a certain amount before the bar begins to work. If you install spacers to make the bar work full time, the ride will stiffen a bit, but the lag will be eliminated. Or you could add one of the bars described in the following paragraph.

The other type of bar is the EMPI-developed flat steel bar which pivots under the transaxle. It is available for all swing-axle VW's. Any bar of this type which you buy will be either made by or built under an EMPI license because they hold patents on the device. Camber-compensator bars are easier to install than the factory Z-bar.

Two firms make most of the anti-roll bars for the VW: EMPI and ADDCO. Because there is such a wide variety, a table is provided here to sort out what's available. You can buy the bars from many VW dealers, from speed shops, and mail-order houses including Midwest, Honest Charley, J. C. Whitney, Warshawsky, and direct from the manufacturers. Because the prices vary, don't hesitate to do a little shopping, remembering to add in the freight or postage if you are buying by mail.

DECAMBERING

Decambering (setting the front and rear wheels at negative camber in the static or unloaded condition) is usually done to improve VW handling. It is nearly always accomplished at the rear wheels, but the front wheels can also be decambered to improve front-end "sticking power". The process lowers the roll center to reduce weight transfer to the outside wheels in cornering. It also improves the cornering power available from the tires (as long as excessive amounts are not used) because the tire is flattened against the road in cornering to improve its contact patch or footprint. This is shown in the accompanying drawings from an article by Dunlop Tyre's racing engineers. They also pointed out the need for setting transverse-link-type rear suspensions (such as the '69 and later VW) at about 2^{0} negative camber for maximum cornering power.

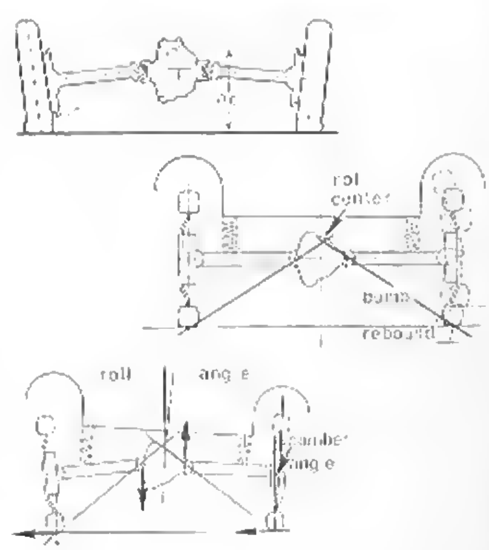


Rick Knoop of Atherton, Calif. is shown as he tightens the last nut on an ADDCO rear stabilizer bar for his 1970 beetle. These must be used with a heavy front bar.

ADDCO rear stabilizer bar installed on swing-axle VW.

Drawings from *The Motor* (British) illustrate the jacking effect occurring during cornering with a swing-axle-equipped car such as the VW, Porsche, Corvair, Renault, etc. This is caused by the difference in cornering forces on the inner and outer tires. Cornering "jacks up" the roll center of the car above its static-loaded position, producing a change toward oversteer, and sometimes allowing the inside rear wheel to spin so that power and time are lost. To reduce this phenomenon, or keep its effects within reasonable limits, the enthusiast owner often sets the rear wheels of his swing-axle VW at 3^{0} to 5^{0} *negative* camber in the static-load position. This accomplishes three things:

1. It lowers the roll center and helps to keep the rear wheel from "jacking" so far that it loses contact with the ground.

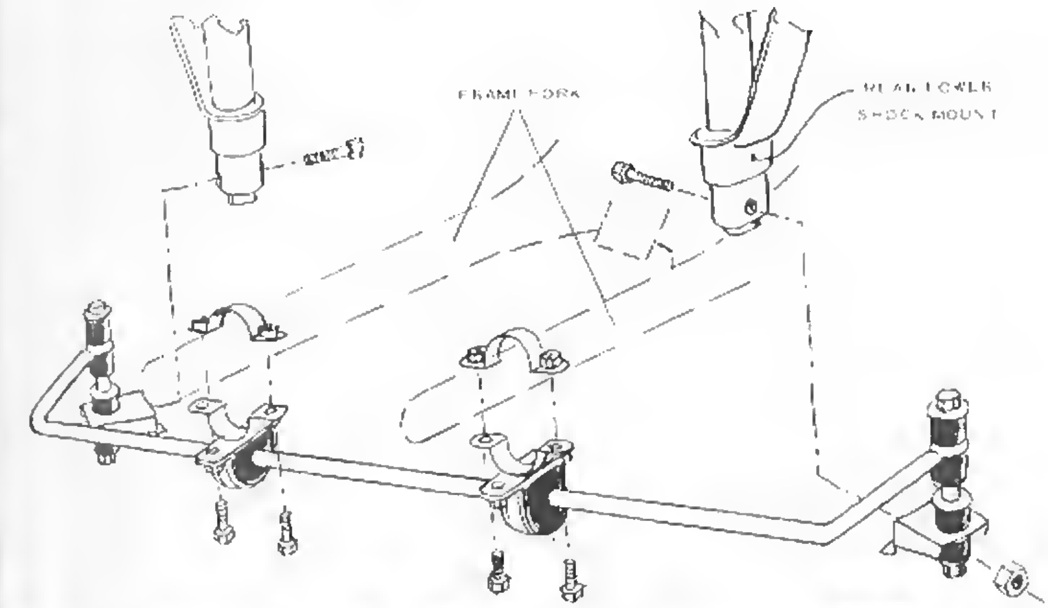


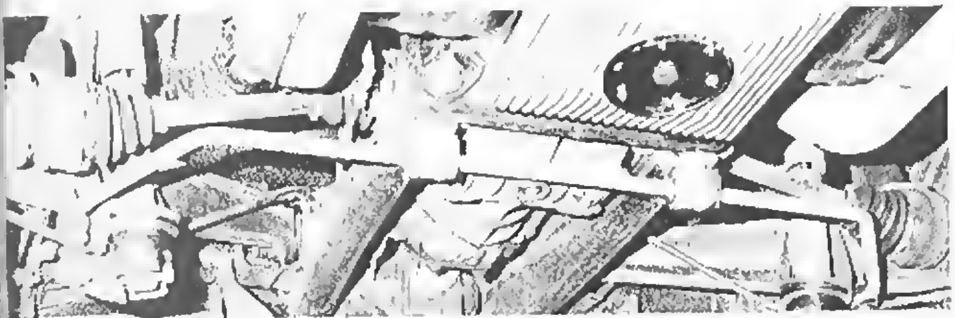
2. As "jacking" occurs in cornering, the wheels move toward neutral camber, or to a less-positive camber position than would occur with stock settings.
3. Reduces ground clearance.

The use of negative camber is an important part of chassis tuning. Swing-axle VW's are not "pure" swing-axle cars, but use a combination of trailing arm and swing axle. The rear wheels swing in two arcs: one around the control-arm pivot, and the other around the U-joint. This is similar to the designs used by Lagonda, Porsche, and Corvair. The net effect provides a slightly lower roll center than a true swing axle would provide.

There are disadvantages in using negative camber with each of the VW's rear-suspension systems: slightly uneven tire wear, and decreased ground clearance. Decambering increases the toe-in (tending toward understeering). The toe-in must be reset by moving the axles back in the slotted trailing arms to get the desired toe-in setting to reduce wheel "scrub". Toe-out may make the wheels tend to follow a straight path (tilt a wheel inward and roll it to see what it does), but may also make the car harder to handle. So, the setting for minimum scrub may not coincide with settings which provide the exact degree of under/oversteering which you find best for your own driving capabilities or for the type of course on which you most often run. Here again you should reread the Stability Chapter.

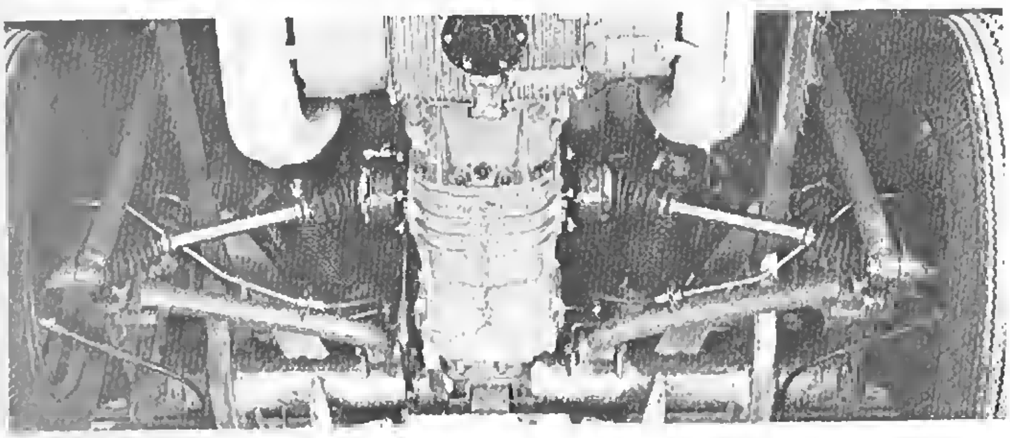
Also, there must be a compromise between the 2^0 negative setting recommended by Dunlop for maximum traction in cornering and a setting which will get the rear end low enough to offset "jacking". Regardless of the experimentation which will be required to get the maximum benefit from your decambered VW, it is safe to say that any VW which is to be driven vigorously needs the benefits afforded by simple decambering, especially at the rear.





EMPI rear Camber-Compensator bar installed on 4-joint 1970 beetle. Note added oil sump. Drawing shows parts and installation details.

Four-joint became standard on all 1969 VW's. The arrangement vastly improved the stability and roadability of the cars and provided a softer ride at the same time. Front ball-joint-spindle suspension became standard in 1966. It is used through 1971, except on Super Beetles, which have a MacPherson-strut front suspension.

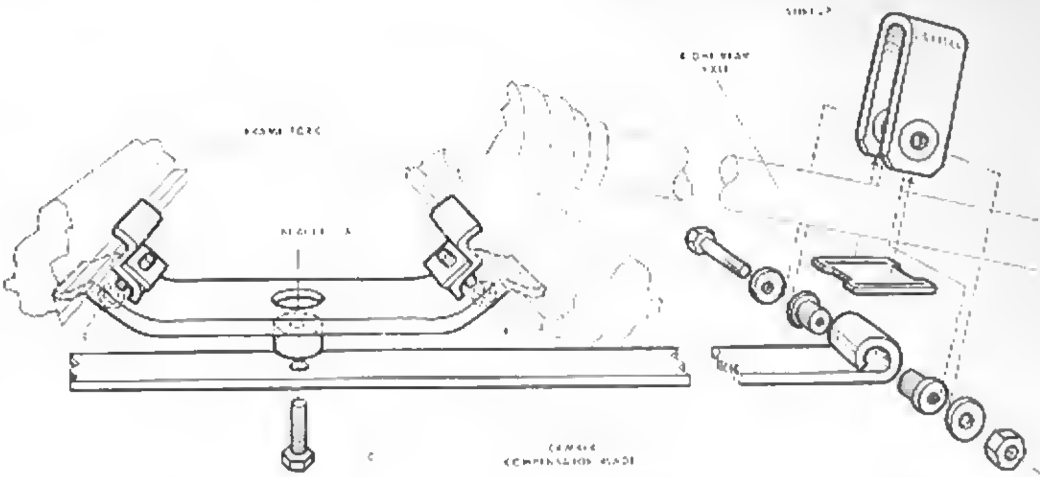


WHEELS

Replacement wheels in a wider width are an important purchase for the VW owner who wants maximum cornering performance for driving pleasure or for competition. The VW stock wheels are 4- or 4.5-inch rim width. Most owners never bother to change wheels and they miss out on one of the finest improvements which they can make to their cars and one which is low in cost.

Wider wheels can be built from your stock wheels, but the special tools and precision which are essential should keep this kind of work in specialty wheel shops. Sometimes the inner portion and center of one wheel is welded to the outer rim section of another wheel. Or the outer rim of a wheel can be cut off and welded back in place with a steel band between the two original pieces. However, with the availability of high-quality stamped-steel centers to fit the VW bolt pattern, the trend is to use one of these with a ready-made rim in the desired width. Details on tolerances and on constructing wheels for off-road use are in our book, "BAJA PREPPING VW SEDANS & DUNE BUGGIES."

Should you be looking through a catalog and see a wheel "that turns you on"—but no rim width is mentioned—forget it unless you find out that it is at least 5.5" wide and preferably 6" because there will be very little difference between the prices that you'll have to pay. Should you be looking through a catalog and see a wheel "that turns you on"—but no rim width is mentioned—forget it unless you find out that it is at least 5-1/2" width. Many of the "wide" wheels that are sold for VW's are stock width or 5" and this slight increase is just not worth the price of the wheels. Wider wheels are available from many sources. Most VW specialty shops and buggy shops carry a good stock of wheels. EMPI offers 15 X 5 1/2 wheels in several styles to fit both 4- and 5-lug drums. Prices range from $25 to $50 depending on type and finish. J. C. Whitney and Warshawsky catalogs show 15 X 5.5 steel wheels for about $10 and 15 X 6 mag/steel wheels for under $30. Specialty off-road-tire distributor Dick Cepek has numerous widths in stock and can make whatever width and offset you might need. 15 X 6 wheels typically cost about $20 each. Honest Charley's catalog lists aluminum wheels ranging from 14 X 6 through 15 X 10 with prices starting around $46. Midwest's shows both steel and aluminum wheels for VW's in various widths and diameters.



EMPI rear Camber-Compensator bar installed on swing-axle VW. Drawing shows parts and installation details.

When you buy wheels, look them over with a careful eye before you load them into your car or allow tires to be mounted on them. It is all too easy to accept a wheel which the parts man or salesman does not know is damaged and he may think that you damaged it when you bring it back in. If you buy by mail, examine the package immediately when it comes. If there is any damage such as a bent wheel, you want to be back with it the same day or the next day at the latest to get another one. If you find a spot that is bent or damaged, circle it with chalk or spray the area lightly with paint so that the trouble spot will be immediately apparent. Be sure to measure the offset and the rim width when you get the wheels—before you mount the tires.

The edge of a magnesium or aluminum wheel may be chipped, or there may be a casting irregularity. The rim of a steel wheel may be bent so that there is a flat spot. It is so much easier to reject the wheel before you pay for it instead of trying to get satisfaction later on. Mounting tires on cast wheels can chip the rim, so examine the wheels carefully before giving them to the tire specialist. If he wants an extra few dollars per wheel to mount the wheels, don't complain. It'll be worth it to have the job done right with-without scarring your wheels or breaking off the rim edges. Don't give the tire-mounting job to a firm that has never handled cast wheels because they are not likely to buy you a new set when they wreck yours. It's best to do some inquiring among your friends who have mag or aluminum wheels. They'll probably know someone who can do the job for you.

Chassis tuning with wheel (and tire tread) width is an accomplished fact. Many racers use stock-width or slightly wider wheels at the front, with very-wide wheels at the back. This size differential tends to reduce the

Chassis Engineering's bolt-together aluminum wheels for VW's are the lightest you can buy for racing. Here is a bare C.E. wheel, one on the back of a beetle, and one on a buggy.

oversteering tendency. There is plenty of room for experimentation to get the chassis perfectly mated to the type of racing you are doing.

Reversing wheel rims so that the major portion of the wheel is placed toward the outer edges of the car may look very stylish or "Kustom Kar," but the technique is not recommended for VW's. Fender wells will be fouled by the tires, and the rear axles are subjected to excessive loads which may lead to premature axle breaking. In addition, reversed wheels are not really needed because VW is already a "wide-track" vehicle, equaling or surpassing all recent cars with that designation . . . including Pontiacs. The VW tread is 54% of the wheelbase at the front and 57% at the rear. Money which you might spend on reversing or chroming wheels should be invested in at least two special wide-rim wheels for the rear. Add them all around if your budget permits. NOTE: Wheels should be inspected prior to each competition event, regardless of the care which has gone into their construction or the use which they've had. Drag racers will want to consider getting a super-low rear-axle ratio by using small-diameter rear tires. The center of a VW wheel can be married to a 13-inch rim from a Corvair or Comet, using a 5.20 X 13 tire. Or, use a 12-inch Opel, 1100 MG or 1100 Austin rim with a 4.20/4.60 X 12 tire. You'll knock at least a quarter second off your quarter-mile ET, according to Car Craft editors.

RACING WHEELS

There's just one kind to consider: Chassis Engineering. Fred Puhn who owns Chassis Engineering is an experienced engineer turned race-car builder/owner/driver. He set out to build the lightest possible wheels and ended up with a product which is considered to be the best in the business. His monocoque wheels are made from two spun-aluminum (6061-T6 wrought alloy) halves which are bolted together and sealed with an O-ring and Silastic.

Either rim half can be replaced if it's damaged—at far less cost than buying a complete wheel. And, rim width can be changed by simply buying a new wheel half. Mounting tires is not as easy as it might appear, according to racers who are using the wheels. You'd think that the wheels could be split and then bolted together with the tire between them. If you mount the tire in this manner it is easy to pinch the tube if you are using one, and it's difficult to install the O-ring and seal it with Silastic because the tire has to be held away from the center. So, most racers assemble the wheels, do any required sealing and then have the tires installed on a tire machine. They point out that the C.E. wheels do not chip when tires are mounted on them with a machine—a common problem with cast-magnesium or cast-aluminum wheels.

The wheels are half the weight of a steel wheel with the same width and at least 20% lighter than a cast-magnesium wheel of equivalent dimensions. Typical weights are 6.3 lbs. for a 13X6, 8.8 lbs. for a 15X6, 9.9 lbs. for a 15X8, and 7 lbs. for a Super Vee 13X6. The aluminum deep-dish construction of the wheels helps to cool the brakes if adequate ducting is provided. Otherwise, stagnant air inside of the wheel can make brake cooling a problem because there are no slots in the wheels.

Puhn claims that his 13-inch C.E. wheels for Super Vees are absolutely the only ones which should be considered because they clear the extra-big VW disc brakes at the front without any need to use thin cross sections. Cast wheels must be thinned excessively to fit over the discs.

When you stack up all of the advantages, the prices of $75 to $90 each don't seem at all unreasonable.

WHEEL OFFSET

"Offset" is a term often heard in discussions of wheels. Offset is the distance the rim is moved out or in from the mounting surface of the wheel. A wheel has no offset if its mounting surface is at the centerline of the rim. If the rims are moved out, giving the car a wider track, the wheels are said to have a positive offset. If the rim is moved in, narrowing the track, the wheel is said to have a negative offset. A positively offset wheel is sometimes used to move large tires away from inner body panels, especially with rear tires on VW sedans. The amount of positive offset must be kept to the absolute minimum required for clearance and even then, you may find that the fenders have to be reshaped or swapped for fiberglas ones. More than one VW owner has given up in disgust—with a set of "boss-looking" tires and wheels on his hands—'cause he couldn't afford to buy special shocks, fenders and/or body work to make it all work together.

WHAT SIZE TIRE?

The availability of wider tires and wheels has dramatically improved VW's handling capabilities in braking, cornering and acceleration. They also make your VW look like it "means business." There's one major problem: wheels which are too wide and tires too large in diameter and/or too wide—will foul the fenders when the suspension allows the body to "sit down" onto the tires.

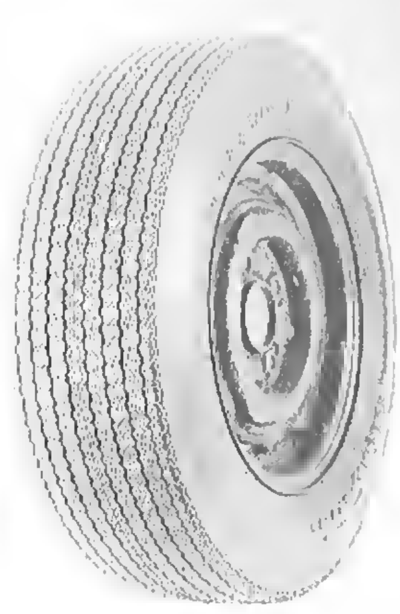
Big-diameter tires may look "boss," but keep the gear ratios in mind by thinking of the tire as a gear ratio. Remember that the stock VW 4th gear is already an overdrive which cuts down on through-the-gears performance. The stock 25.5-inch-diameter tires will usually let the VW reach a true top speed of about 73 to 80 mph on a straight, level road with no wind. Hang a set of larger diameter tires on the back and the car will accelerate less rapidly and run slower flat-out. The larger diameter tire gives you an effectively higher gear (lower, numerically) ratio. This is often true, even with close-ratio 3rd and 4th gears. Further, the man who does this sort of thing—to get "looks" or to gain clearance for off-road use—finds that he has to drop back in the gears much sooner than with the stock-size tires. Hills that once were climbable with 3rd gear now take 2nd. But, install smaller diameter tires and you have effectively changed the gear ratio to a lower ratio (higher, numerically) and the car accelerates faster. Many VW enthusiasts install close-ratio gears, using these with stock-size tires for around-town running and switching to a short (smaller-diameter) tire for drag or slalom racing where still more acceleration is needed. Unfortunately, the 15-inch wheel size limits your choice of tires, especially with smaller diameters. Most tires, especially those that give you a wider tread width for better handling, have a larger diameter. 14-inch wheels are no solution, either. For this reason, 13-inch wheels are often mounted on the VW. Goodyear's Bias/Belted Polyglas A70-13 should be a winner on the VW. The tire, first introduced on the 1971 Chevrolet Vega, has a diameter of 23.3 inches and a 6.2 inch tread width. Most important, it is a street tire, designed for everyday use and exhibiting none of the idiosyncrasies of racing rubber.

Tom Cepek of Cepek Tires in Southgate, California, says that a lot of his VW customers mount E70-14 tires on 14 X 6 slotted wheels at both front and rear. By avoiding any offset, interference is usually avoided. Such wheels are sold by Cepek for $16 or $23 each, depending on whether the buyer wants black or chrome finish. These tires, with 26.2-inch diameter, will reduce stock VW performance. Russ Means, Parts Manager for Economotors VW in Riverside, California, says that anything bigger than 7.35-15, E70-15 or a 185R15 on a 6-inch rim will cause some interference unless you experiment with negative-offset wheels. Even these sizes will occasionally cause interference problems, as well as reducing acceleration. Means has had some customers who've gone to ridiculous extremes, using a 12-inch-wide Indy tire on 13-inch wheels. They get by with super-stiff helper spring shocks. The ride becomes fiercely rough and the damage which is done to the suspension and transaxle is hard to imagine. If you have a bad back or weak kidneys, the slot-car look—mean as it is—may not be worth it.

Don't expect tire charts to provide the gospel truth. They give no real clues as to section or tread width, or even the diameter. They only indicate which sizes interchange to provide *similar* load-carrying capabilities.

If you will be setting up a VW strictly for racing or plan to have an extra set of racing tires, the Goodyear Blue Streak Sports Car Special 5.75/8.90-13 with 24.8-inch diameter and 6.8-inch tread width would be worth checking into. Or, you may want to consider using the 5.00/9.20-15 with the same diameter and 7.1-inch tread width. Other tires with wider treads are supplied by Goodyear, but there are serious fender-well interference problems and you'd better be sure that you know what you are doing before investing your next month's pay.

Vito Caravito of Goodyear's Racing Tire Group says that the "60" series tires are kissin' cousins to the best racing rubber which was used a couple of years ago. These tires are designed for everyday use on your car and they'll work as dual-purpose rubber for occasional autocrosses or whatever.



Goodyear Polyglas A70-13 should work well on dual-purpose VW's. 23.3-inch diameter should help acceleration. Tire puts 6.2 inches of rubber on the ground. Should be used on at least a 5-inch-wide rim and can be used on rims to 6-inch width.

E60-15 Goodyear Polyglas tire works on 6-inch or wider rims, puts 7.7 inches of rubber on the ground. 25.5-inch diameter will work well with close-ratio gears.

The figure "60" indicates a tire height from bead to tread surface of approximately 60% of the tread width. High, old-fashioned, conventional tires are 83% as tall as they are wide. The low-profile, narrow sidewall tire is far better for high-speed control than the earlier tires. However, you'll need to check their fit on your VW *before buying* them to make sure that they will fit without drastic body and/or suspension modifications.

When fitting a very wide tire, the first thing to remember is to work with another person so that there are two sets of eyes watching for interference. Above all, don't just put the tires on and start checking for interference with the car on the ground and you turning the front wheels by yourself. The tremendous leverage available through the steering mechanism can allow you to slice large chunks out of the tire if you force the tire past the sharp edge of a fender well. Here's where another person can be extremely helpful in watching what is happening throughout the turning of the tire from full lock in each direction. Actually it is best to put on one wheel at a time and check that one wheel and wheel opening for clearance.

It is somewhat difficult to check wheels and tires for clearance at full bottoming unless you can have several fellows pile onto that corner of the car to bottom out the suspension. Do this progressively so that you can observe as the wheel moves into the fender well. This sort of checking should be done with the rear wheels and with the front wheels. The front wheels need this checking at straight-ahead, full-left and full-right-turn positions because you may encounter different points of interference in these different attitudes. There's usually no interference to be concerned with when the car's suspension is fully extended—as if the car were flying after a bump.

The most usual points of interference are the outer edge of the rear tire with the center of the wheel-well top. The lip there may have to be eliminated or rolled up to give sufficient clearance, especially with the suspension fully bottomed out.

At the front, the wider tire essentially has a larger diameter as you turn the wheel to full-lock. The forward outside edge of the tire may contact the inside bottom edge of the forward outer edge of the wheel well. The outer edge of the tire may contact the wheel well in the center by the lip, just as on the rear tire.

If you will be driving your car—or racing—in a class which allows using wider fenders, by all means bolt on a set of Crown Manufacturing's fiberglass ones. Rolling out the edges of fenders and reshaping them will usually cost far more than these complete replacements.

The 4-joint rear VW's are easier to fit with large tires because the rear wheels move up and down in almost a straight line (little camber change with suspension deflection). Thus, you only have to contend with the tire diameter and the radius at the top of the fender well, plus whatever might be on the inside of the tire, such as the trailing arm, shocks, etc.

RACING TIRES? NOT FOR THE STREET

I used to run Goodyear Blue Streak Sports Car Specials on the street and wondered why they were so rough in cold weather and always lost air. The thin side walls obviously required parking with exquisite care, but there were other things which I didn't know about the tires. After chiding me—and all others who've run such rubber on the street—Vito Caravito of Goodyear's Racing Tire Group supplied the following information. I'll quote him directly so that you'll have only yourself to blame when you are stopped and cited by the men in blue for using racing rubber on the street or highway.

Caravito says, "Goodyear Racing Tires are specifically designed and compounded for racing only on a closed circuit under supervision and are NOT to be used for street or highway use. *It is now illegal to mount or use race tires for highway use* because they have not been subjected to the U. S. Department of Transportation's tests (FMVSS 109). Due to the conditions under which they operate, there is no warranty, guarantee or liability applicable to Goodyear racing tires and tubes.

"Goodyear's Racing Tire Group gets complaints on the limited availability of racing tires. They are difficult to buy because they are made in small lots and may not have aging protection in the tire. We don't want the tires deteriorating in a warehouse. Further, Goodyear and other tire makers do this purposely to discourage use on the street.

"Because of the temperatures required to make racing tires 'work,' users in cold climates will find that the racing tires are quite slippery in cold weather—literally providing all the 'tractive effort of a rock.' No one can keep the tires 'up to working temperature' on the street. Such temperatures might be reached occasionally, but the tires would cool off in the first slow corner, straight stretch, or stop light. The tires don't really start to 'work' until they get to a temperature of 150°F or higher. And, they may act like the road is wet glass when it rains, especially 'dry' tires.

Goodyear often gets complaints about having to pump up racing tires every morning from people using them on their drive-to-work cars. Caravito points out that racing tires are not designed to hold air for long periods of time. "They are inflated prior to a race and they'll hold air for at least the duration of the event, which is what we designed them to do.

"Passenger-car tires certified for highway use must withstand brutal penetration tests, excessive loadings, high speeds and so forth. The race tire can be expected to withstand the racing conditions for which it was designed. The two sets of conditions are not necessarily the same.

"When you decide to buy racing tires for use on a race course, talk to a Goodyear Racing Tire Distributor directly. There is no sense in sending tire orders to Akron to the Racing Tire Division. In fact, this usually delays the order by about two weeks because the order is automatically sent back to the nearest racing-tire distributor—who then has to get in touch with you. Racing-tire distributors are set up to handle orders for racing tires. You may even have to go to the race track to buy tires (expect to pay cash) that are very popular."

FRONT WHEEL CASTER

Added caster at the front is sometimes helpful in reducing "plowing" when everything else is working well. This is because the caster gives negative camber to the outside wheel, making it stick or "bite" better in a turn. However, added caster can promote instant oversteer by transferring weight to the rear as the front wheels are turned, raising the front of the car. Toeing-out the front wheels–up to 3/4" on short tight courses–is often done to help stop front-end "plowing."

SPINDLES

If you really plan to drive your link-pin-model VW to the limit, install Porsche spindles. They are stronger and will stand up well in the rigors of autocrossing. Spindles and link pins should be regularly Magnafluxed—even Porsche ones–at least twice a year if you are racing regularly. They have been known to break.

STEERING DAMPER

There's no universal agreement about using the steering damper. Some autocrossers use it—others take it off. Suit yourself.

BRAKES

Whether you use stock or replacement Frendo Competition linings, leave the drums in their rusty-iron finish or give them a coat of non-insulating flat-black paint. Drilling the drums does not aid cooling. Polishing, chroming, or painting them white or aluminum is absolutely forbidden. Any such changes reduce drum cooling. Vented backing plates are of little help in brake cooling unless scoops in the airstream are hose-connected to the backing plates so that air is forced through the brake assembly.

Metallic brakes of the Velvetouch variety are available for the VW. They are undoubtedly a good thing to use on busses, but there's some question as to the validity of their use on sedans or fastbacks. These small sedans have reasonably adequate brakes for most driving, but it is possible that the metallics could be helpful in an autocross situation where the brakes could be kept warmed up sufficiently. The only problem with metallic brakes is that they must be warm to be useful. Try to stop some cold frosty morning with a set of the metallics that have not been warmed up by dragging the brakes or several stops in succession. That first stop can be frightening because you think you'll never, ever get slowed down in time. And, you may not.

Regardless of the type of brakes which you use, change the fluid to a Heavy Duty SAE 70R3 after flushing the system with DECLENE Flushing Fluid which is available from GM dealers.

WHEELS CAN AFFECT BRAKES

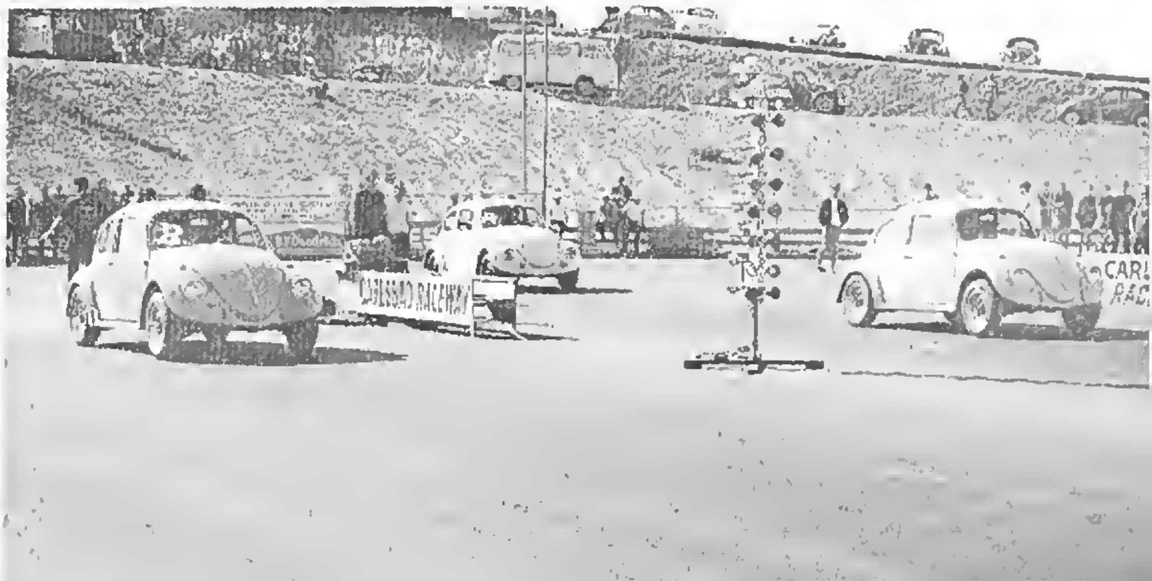
Sounds ridiculous, doesn't it? Gene Berg tells us that you can get jumpy brakes instantly by merely retightening the wheels in place. It distorts the drums every time just enough to cause problems with the brakes. What's the answer? Don't take your wheels on and off or move them from drum to drum any more than is necessary. If you have to take a wheel off, take the drum off too. After mounting a tire, attach the wheel to the drum again–then take the assembly to a brake shop and have the drum turned with the wheel mounted on it. A five-thousandth truing cut usually cleans up the distortion and you'll have brakes smoother than when your VW was new.

SPACERS & WHEEL ADAPTERS

Spacers and wheel adapters are not recommended. Why? Because the spacer must be held on with the wheel–requiring long bolts or intermediate bolts–which must be kept extremely tight, thereby promoting drum distortion. The longer bolts easily loosen because the wheel tends to wiggle them in the drum. Adapters are not recommended because they must also be tightened with a lot of torque, causing drum distortion. When you add this problem to the fact that a set of adapters means you have an additional 16 or 20 bolts to keep tight–making as many as 40 bolts in all on some setups–the adapters become "bad medicine" indeed.

When you are tempted to buy adapters to allow you to install cheap U. S. wheels because they have wider rims, don't. Grit your teeth and save your money until you can do what's right. Wider wheels are available for the VW and that's what you need to buy or have made . . . wheels that fit and that are held in place with the stock quantity of lug bolts.

Serious drag racers must use the latest "trick" compound tires to keep up with the other top runners. VW's often run faster at the drags with smaller diameter tires and wheels, especially with stock or near-stock engines.



WEIGHT DISTRIBUTION

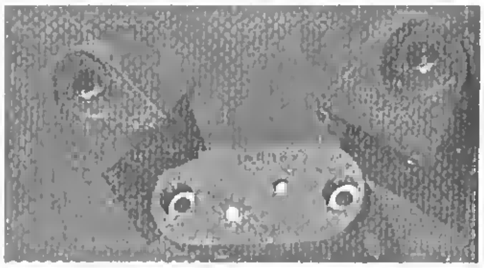
Anything which you do to reduce the rearward weight bias assists in improving your VW's handling. For instance, the battery can be shifted to a secure up-front mounting. If rules do not specify carrying jacks, tools and spare tire—throw 'em out. Sometimes, seats can be removed or lighter ones used. Reduced weight means increased acceleration and improved braking, too. But, as described in the Stability Chapter, it creates other problems.

Make the rules work for *you*. Study them carefully to see where your fellow competitors can take advantage. It's a battle of wits, as well as horsepower and handling. If you intend to race and win, chances are you'll be willing to forego some of the creature comforts such as radio, tape deck and the like—to get the weight down.

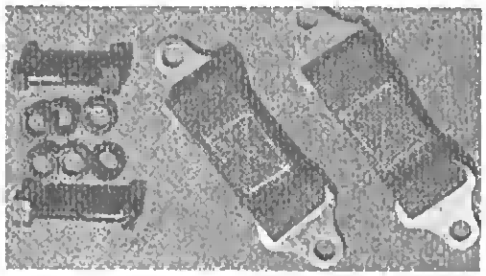
TRANSAXLE & REAR ENGINE MOUNTS

Regardless of camber setting, if the rear wheels are allowed to hop, as caused by rough surfaces and/or over-inflated tires, the "jacked-up" rear end will temporarily drop to the static-load position and cornering power at that instant will be reduced drastically. Rear end hop is also caused by soft transmission and engine mounts and by lack of a rear engine support.

A rear engine mount is essential for the wheel-spinning starts needed for best autocross times. Some competitors like the solid transaxle mounts; others prefer Crown's Trans-Strap and Trans-Support which wrap the transaxle in a solid grip of rubber-cushioned steel. Any of these modifications greatly increase transaxle life because they help to eliminate wheel hop—a fierce destroyer of transaxles, even when they are equipped with Crown's Beef-A-Diff which adds two extra spider gears. Needless to say, any mounting more solid than stock will make your car noisier because the transaxle noise and vibration will be transmitted directly into the structure.



Crown solid mounts for transaxle to eliminate wheel hop on takeoff. Should be used with a rear engine mount, too.



Alray offers straps to prevent rear-axle from tucking under and thereby jacking up the center of gravity in sharp corners. Not recommended for competition because strap lifts the inside wheel, causing a loss of traction at that wheel. Straps fit all swing-axle VW's, are available at Alray, 5814 N. 7th St., Phoenix, AZ 85014.

TRICKS OF AN AUTOCROSS CHAMPION

Now that we've observed the generalities of what can be done to make the VW handle, let's look at what autocross champion Karl Barnett did to make his 1955 VW the number-two runner in Northern California competition for 1969. Karl is a 23-year-old accountant from Half Moon Bay, California. This, his very first automobile, was obtained when he was 16—so he knows it inside and out. As I have pointed out elsewhere in this book, Karl was quick to say that anyone who wants to build an autocross machine must first decide what he is willing to sacrifice in the way of ride and handling—because each apparent benefit has an offsetting disadvantage.

The car races in the Prodified Over-1450cc Sedan Class of the Northern California Sports Car Council—against Corvairs (many of which are turbosupercharged) and all other over-1450cc sedans except pony cars.

Porsche brakes were added to the car long before there was any plan to go autocrossing. The need for better binders on the VW cannot be argued, of course. It's obvious. The 12.5-inch outside diameter of the Porsche brakes dictated how the wheels could be built. NCSCC rules permit 50% wider than stock wheels, rounded up to the nearest half inch. Thus, 6-inch-wide rims are permitted on a VW because stock rims are 4-inches wide. The 6-inch rims were welded to the VW centers with positive offset on the rear wheels to get the maximum tread which could be accommodated in the fender wells—54 inches—with the tires to be used. Front wheels are negatively offset to give a 53-inch tread: the maximum which will fit under the stock fenders. Goodyear Sportscar Specials, 5.00x9.20-15 with an 8-inch McCoy cap, are blown up to 38 psi at the rear and 34 psi in the front.

Barnett claims that some autocrossers are using Corvair's 5.5-inch rims on adapters to get wide rims at low cost—with a good selection of racing tires available. However, Barnett prefers the 15-inch wheels for still another reason—the tires give a longer footprint and thus provide more cornering power than 13-inchers. Goodyear's 5.75/8.90-13 Sports Car Specials are also 24.8-inch diameter, provide a 6.8-inch tread width. . . and should work well on the VW. Don't use the racing tires on the street for a number of good reasons, all relating to your own personal safety.

The next change to make after adding the wide wheels and sticky tires is to modify the front and rear suspension. Starting at the back, the rear wheels are decambered to 2.5° negative (minimum, with the EMPI camber compensator installed) and the ends of the axles are moved rearward by using 3/8-inch aircraft bolts in the trailing arms. You can elongate these slots by grinding—but those trailing arms are tough springy steel. The trailing-arm-to-axle relation is set so that the rear wheels toe-in 1/8-inch. This much toe-in promotes oversteer. A camber compensator is bolted into place under the '64 transaxle. With the car on stands and both axles hanging down, Karl has to use a jack to get the bar close enough to attach it to the axle, because the late-style bracket preloads the straight compensator bar (the type designed for the car in its stock form).

The driving position of the axle at negative camber preloads the bar—helping to ensure that the inside rear tire stays in contact with the pavement, even as the swing axle "jacks" (no way to get away from that phenomenon) during fierce cornering.

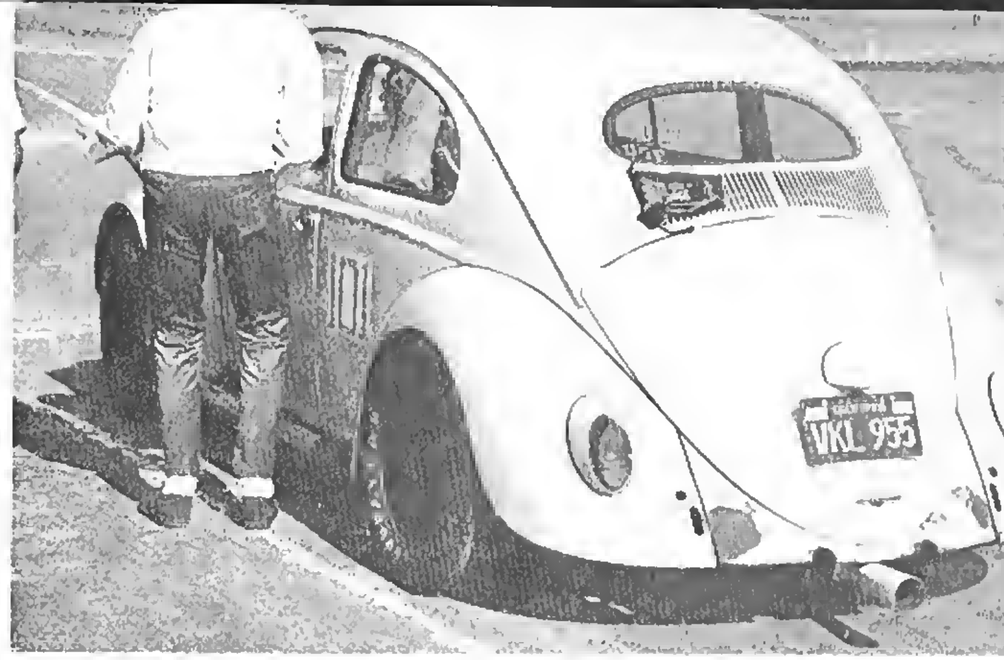
The preload amounts to about an extra 100 pounds at each side, which is a big help in keeping the sticky tires sticking. Once the bar is attached, the Koni shocks are bolted in.

Another EMPI item was bolted in at the front—the 5/8-inch heavy-duty anti-sway bar. Because the car still "plowed" a bit at the front, it's possible that a stock VW sway bar might get the job done even better, but Karl elected to carry 40 pounds of ballast in the spare-wheel well to make the suspension settings work better at the "sticking" process. Karl says that the sandbag helps the front suspension *use* all of the caster and camber by making the tires *work*. He claims that front-end lowering is essential for autocrossing, even though it's not the answer for the street.

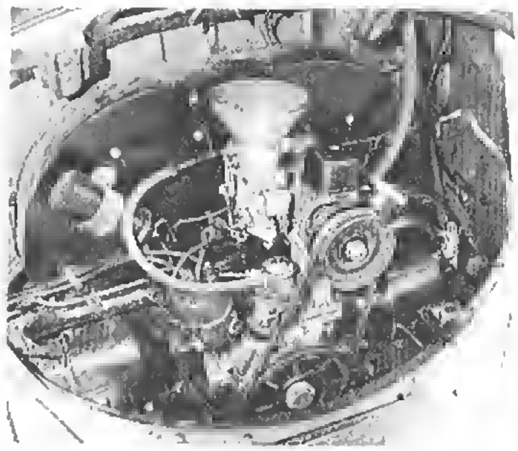
Drastically increasing the caster at the front by using three shims at each side, on the bottom torsion-bar tubes only, makes the outside wheel assume a slightly negative camber during cornering, thus improving its sticking power. Still more negative camber is obtained by a juggling act with the link-pin shims. The link-pin bushings in the torsion-arm links must be sloppy and well-worn or the link pins will bind. Just one shim is used on the inside at the top link pin—and 9 on the outside. The bottom pin gets an exactly opposite treatment: 9 shims on the inside and 1 on the outside. This setup gives the front wheels about 1.5 degrees negative camber. When using this drastic combination, it is important to make sure that the torsion-arm link does not touch the spindle carrier except through the shim faces. Slight grinding may be required.

Note: This type of setup should really be used with remachined torsion-arm links if they are legal.

The front has been lowered by sawing out torsion-bar laminations so that only three full-width lams are on the bottom—and two on the top. By By taking off the rubber snubbers at each side without repositioning the stops, the car has about 3/4 inch travel before it bottoms at the front. With this little movement available, a set of worn-out stock shocks is adequate. No quick-steering arms were available when the car was built, so a small-diameter steering wheel was used to get a similar effect. This makes the car hard to steer, especially with all that caster. You literally lift the car over-center whenever you go from a left bend to a right bend.



1



2

3

1 - Karl Barnett receives instructions from starter at 1969 Santa Maria, Calif. North/South Autocross. Note lip on front fender, tight fit of rear tire. 2 - Barnett's engine looks stock. Screened entry to cheap aluminum funnel keeps out rocks and bugs. 3 - The happy owner, Mr. Barnett himself. 4 - Compensator is not stock, combines bracket from late ('64) kit with straight bar for 1955 car. Curved design compensator bar is used on later models.

4

A car set up like this one is so definitely "twitchy" that some would call it unstable, especially at high speeds. The rear end can be tossed out almost by just thinking about it. Want the rear end out, say at 50 mph in 3rd gear? No problem—just set it up with the steering wheel and around it comes—which Karl feels is ideal *for the average autocross event.*

Although we've concentrated on showing you what Karl has done to make the car handle to get it through autocross courses in the biggest hurry, a few words are in order about the power train. The engine is a 61 case with 1500cc barrels and pistons and a late 1600 "F" crank with directional oil grooves in the main journals. 1200 pins and rods are used, with the rods narrowed at the big end to take 1300/1500-size bearings. An Engle cam pops the stock-size valves which are in 1300 heads flycut 0.100 inch. Rules permit any intake setup—so long as you run the basic stock carburetor, so Karl built his intake manifold out of exhaust tubing, providing a smooth upside down Y under the carburetor which is a 28PCI Solex from the old 36HP engine. The venturi has been removed and the throttle shaft thinned so that the carburetor will flow the maximum possible amount of air. Two gaskets are run under the needle and seat to lower the float. There's no exhaust heat to the carburetor, of course. We'd estimate an honest 60HP is pushed through the 200mm diaphragm clutch which lives in a 10.5-pound lightened flywheel.

Because the rules won't allow drastic lightening, only the back seat has been removed, along with all sound-deadening insulation, lid latches and springs, and everything out of the dash—to get the weight to 1550 pounds. The door panels and head liner are as intact as you'd expect for a 15-year-old car that's had a hard life. A lot of competitors "put this car down" when they first see it on the starting line or in the pits . . . scruffy with rust spots here and there amidst what was once yellow paint. But unpleasant thoughts and doubts leave quickly when Karl or other driver Frank Kukula bring the r's up, sidestep the clutch and boil out of the start into the first corner—there goes the rear end out and he'll surely lose it—no, well, he'll never get through another corner without spinning. On to the next corner—he must be going way too fast—but out comes the rear end again and—wow—there's no way . . . and the announcer tells us that the little yellow VW has just posted the fastest time of the day for the sedan class. Some things are hard to believe—and Karl Barnett's 1955 VW sedan is one of them.

HANDLING TABLE for Beetles, Fastbacks & Squarebacks

	Road Stage	Dual-Purpose Stage	All-Out Stage
Anti-Roll Bar, Front	5/8 or 3/4 inch	3/4 inch	3/4 inch or adjustable 5/8 inch
Camber-Compensator/Rear Stabilizer Bar	Use for all swing-axle models	Same	Same
Anti-Roll Bar, Rear	Not recommended	Not for swing axle 4-joint: only if front equipped with 3/4 inch anti-roll bar and car is understeering, or to quicken handling	Not for swing axle Same as Dual-Purpose stage for 4-joint
Steering	Adjust to eliminate play, install Crown quick-steering adapter for autocross: all stages		
Shock Absorbers	Stock	Stock or whatever degree of stiffness required	Same as Dual-Purpose
Alignment (autocross use may require different settings to optimize handling for specific courses)			
Front:	toe-in 1/16 to 3/16" caster 2° to 3° camber 0°	Same as Road Stage	Toe-in same caster 2° to 5° (added caster can cause high-speed wobble) camber 0° or for autocross 1° to 2° negative
Rear:	toe-out 0 to 1/8" (swing axle) toe-in 1/16" (4-joint)	1/8" toe-out, swing axle 1/16 to 1/18" toe-in, 4-joint	
	2° negative camber (swing-axle or 4-joint)	2° neg. camb./4-joint 3° neg. camb./swing-axle	2° neg. camb./4-joint 3° to 4° neg. camb./ swing-axle
Wheels	5-1/2 inch or wider standard offset	6 inch or wider std. offset	6 inch or wider Chassis Engineering wheels, std offset.
Tires	Wider-than-stock tread with stock or smaller diameter	Same	Widest tread that fits under fenders, especially at rear
Brakes	Stock or replace with Frendo lining. Porsche front/rear drum or disc brakes for link-pin models	Same as Road Stage except use Frendo competition lining	Same as Dual-Purpose Stage

ACE/Automotive
Competition Engines
19045 Norwich
Livonia, MI 48154
313/477-2879

Addco Industries, Inc.
East St.
Lake Park, FL 33403
305/842-6065
Catalog 25¢

Air World Manufacturin
4210 Vanowen St.
Burbank, CA 91504
213/984-1951

Autobooks
2900 Magnolia Blvd.
Burbank, CA 91503
213/849-1294

Autodynamics Corp.
2 Barnard St.
Marblehead, MA 01945
617/631-8500

Auto World
701 No. Keyser Ave.
Scranton, PA 18508
717/346-7495

Baum Tools Unlimited
7155 Remmet
Canoga Park, CA 91303
213/348-8633
Catalog $1

Gene Berg Enterprises
784 N. Lemon Ave.
Orange, CA 92667
714/538-2067
Catalog 50¢

Racer Brown Cams
9270 Bordan Ave.
Sun Valley, CA 91352
213/767-4062
Catalog $1

Bug-Formance
942 W. El Camino Real
Sunnyvale, CA 94087
408/245-3591

Carbooks, Inc.
2855 Atlantic Ave.
Brooklyn, NY 11207
212/277-0035

Dick Cepek
9201 California Ave.
South Gate, CA 90280
213/569-1675

Chassis Engineering Co.
705 West 13th St.
National City, CA 92050
714/474-3861
Catalog 25¢

Classic Motorbooks
1415 West 35th St.
Minneapolis, MN 55408
612/823-2656

Competition Engineering
2095 N. Lake Ave.
Altadana, CA 91001
213/794-8402
Catalog $1

Crown Manufacturing
858 Production Place
Newport Beach, CA 92660
714/642-7391
Catalog $1

Earl's Supply
14611 S. Hawthorne
Lawndale, CA 90260
213/772-3605
Catalog $1

Edelbrock Equipment
411 Coral Circle
El Segundo, CA 90245
213/322-7310

EMPI
P. O. Box 1120
Riverside, CA 92502
714/868-5104
Catalog $2

Forge Enterprises
3251 Ash
Palo Alto, CA 94306
415/321-2205

Fourtuned Exhaust
5953 Ordway St.
Riverside, CA 92504
714/687-0214

Goodyear Racing Tire Div
1144 E. Market St.
Akron, OH 44316
216/794-4580

Go-Power
1800 Embarcadero Ave.
Palo Alto, CA 94303
415/328-7676

Grant Industries
3680 Beverly Blvd.
Los Angeles, CA 90004
213/382-1375

Honest Charley Inc.
108 Honest St. · Box 8535
Chattanooga, TN 37421
615/892-2114

Manley Performance Eng
13 Race St.
Bloomfield, NJ 07003
201/743-6577

Midwest Auto Specialties
5063 Turney Rd.
Cleveland, OH 44125
216/991-4900

MG Mitten
Box 4156 Catalina Station
Pasadena, CA 91106
213/681-5681

Nu-Metrics
14055 Cedar Rd.
Cleveland, OH 44118
216/932-3100

Race-Chek
Box 5850
Pompano Beach, FL 33064
305/942-5304

Radatron, Inc.
Box 177
N. Tonawonda, NY 14120
716/692-3889

Rajay Industries, Inc.
2602 E. Wardlow Rd.
Long Beach, CA 90810
213/426-0346

Rimco
522 E. Dyer Rd.
Santa Ana, CA 92707
714/539-0350

Kay Sissell Automotive
10829 Slack Ave.
S. El Monte, CA 91733
213/444-8921

Stuska Engineering
1902 W. Colfax Ave.
Denver, CO 80204
303/534-0553

Thermo-Chem
912 W. Skelly Dr.
Tulsa, OK 74105
918/446-6682

VW Speed & Sport
1175 Canton Rd.
Akron, OH 44312
216/733-1932

Warshawsky & Co.
1900 S. State St.
Chicago, IL 60616
312/939-4886
Catalog 50¢

WANT PARTS INFO?

Enthusiasts often complain about "tight-wad" manufacturers who won't answer requests for information or literature. Advertisements in the automotive magazines indicate that catalogs or instructions are typically 50¢ to $1. But, why should you pay a manufacturer for his catalog so that you can buy something from him? The answer has two parts: (1) you probably won't buy anything, and (2) his out-of-pocket costs for sending the catalog (printing, envelope, addressing and stamps) are more than what he charges in every case. He asks that you help to defray literature costs because he has no way of determining whether you are a literature collector, a discount-house shopper, or a bona fide cash customer.

How about letters with questions? Many questions which are asked obviously indicate that the writer has not done his "homework" by reading workshop manuals, magazine articles, or this book. Some intelligent questions would probably be answered if there was room for an answer on a neatly typed letter sent together with a dollar for literature and a self-addressed, stamped envelope for an answer. Indicate on your letter that a handwritten scribble will be fine for an answer—and word one or two questions carefully so that they can be easily answered with a word or two. Some enthusiasts' letters contain such long and involved questions that $100 in time and research would be required to create an answering letter. Even if the manufacturer has the answer "in his head," typed letter costs at least $4—not counting the man's time—whether you buy anything or not. Small wonder that so many letters are thrown out—or that manufacturers react with undisguised disinterest when called upon for information. Selling catalogs and literature is an absolute necessity in the automobile-accessory business. If you cannot grasp that fact, then don't be surprised when your requests go unanswered.

Although H.P. Books and the author cannot answer requests for information on engine-building or chassis setups, I assure you that your letter pointing out where this book could have been more helpful to you, or where there is an error, will always be appreciated.

CONVERSION CHARTS—METRIC TO DECIMALS

mm. Ins.	15 = .5905	30 = 1.1811	45 = 1.7716	60 = 2.3622	75 = 2.9527	90 = 3.5433	105 = 4.1338	120 = 4.7244
.25 = .0098	15.25 = .6004	30.25 = 1.1909	45.25 = 1.7815	60.25 = 2.3720	75.25 = 2.9626	90.25 = 3.5531	105.25 = 4.1437	120.25 = 4.7342
.50 = .0197	15.50 = .6102	30.50 = 1.2008	45.50 = 1.7913	60.50 = 2.3819	75.50 = 2.9724	90.50 = 3.5630	105.50 = 4.1535	120.50 = 4.7441
.75 = .0295	15.75 = .6201	30.75 = 1.2106	45.75 = 1.8012	60.75 = 2.3917	75.75 = 2.9823	90.75 = 3.5728	105.75 = 4.1634	120.75 = 4.7539
1 = .0394	16 = .6299	31 = 1.2205	46 = 1.8110	61 = 2.4016	76 = 2.9921	91 = 3.5827	106 = 4.1732	121 = 4.7638
1.25 = .0492	16.25 = .6398	31.25 = 1.2303	46.25 = 1.8209	61.25 = 2.4114	76.25 = 3.0020	91.25 = 3.5925	106.25 = 4.1831	121.25 = 4.7736
1.50 = .0591	16.50 = .6496	31.50 = 1.2402	46.50 = 1.8307	61.50 = 2.4213	76.50 = 3.0118	91.50 = 3.6024	106.50 = 4.1929	121.50 = 4.7835
1.75 = .0689	16.75 = .6594	31.75 = 1.2500	46.75 = 1.8405	61.75 = 2.4311	76.75 = 3.0216	91.75 = 3.6122	106.75 = 4.2027	121.75 = 4.7933
2 = .0787	17 = .6693	32 = 1.2598	47 = 1.8504	62 = 2.4409	77 = 3.0315	92 = 3.6220	107 = 4.2126	122 = 4.8031
2.25 = .0886	17.25 = .6791	32.25 = 1.2697	47.25 = 1.8602	62.25 = 2.4508	77.25 = 3.0413	92.25 = 3.6319	107.25 = 4.2224	122.25 = 4.8130
2.50 = .0984	17.50 = .6890	32.50 = 1.2795	47.50 = 1.8701	62.50 = 2.4606	77.50 = 3.0512	92.50 = 3.6417	107.50 = 4.2323	122.50 = 4.8228
2.75 = .1083	17.75 = .6988	32.75 = 1.2894	47.75 = 1.8799	62.75 = 2.4705	77.75 = 3.0610	92.75 = 3.6516	107.75 = 4.2421	122.75 = 4.8327
3 = .1181	18 = .7087	33 = 1.2992	48 = 1.8898	63 = 2.4803	78 = 3.0709	93 = 3.6614	108 = 4.2520	123 = 4.8425
3.25 = .1280	18.25 = .7185	33.25 = 1.3091	48.25 = 1.8996	63.25 = 2.4901	78.25 = 3.0807	93.25 = 3.6713	108.25 = 4.2618	123.25 = 4.8524
3.50 = .1378	18.50 = .7283	33.50 = 1.3189	48.50 = 1.9094	63.50 = 2.5000	78.50 = 3.0905	93.50 = 3.6811	108.50 = 4.2716	123.50 = 4.8622
3.75 = .1476	18.75 = .7382	33.75 = 1.3287	48.75 = 1.9193	63.75 = 2.5098	78.75 = 3.1004	93.75 = 3.6909	108.75 = 4.2815	123.75 = 4.8720
4 = .1575	19 = .7480	34 = 1.3386	49 = 1.9291	64 = 2.5197	79 = 3.1102	94 = 3.7008	109 = 4.2913	124 = 4.8819
4.25 = .1673	19.25 = .7579	34.25 = 1.3484	49.25 = 1.9390	64.25 = 2.5295	79.25 = 3.1201	94.25 = 3.7106	109.25 = 4.3012	124.25 = 4.8917
4.50 = .1772	19.50 = .7677	34.50 = 1.3583	49.50 = 1.9488	64.50 = 2.5394	79.50 = 3.1299	94.50 = 3.7205	109.50 = 4.3110	124.50 = 4.9016
4.75 = .1870	19.75 = .7776	34.75 = 1.3681	49.75 = 1.9587	64.75 = 2.5492	79.75 = 3.1398	94.75 = 3.7303	109.75 = 4.3209	124.75 = 4.9114
5 = .1968	20 = .7874	35 = 1.3779	50 = 1.9685	65 = 2.5590	80 = 3.1496	95 = 3.7401	110 = 4.3307	125 = 4.9212
5.25 = .2067	20.25 = .7972	35.25 = 1.3878	50.25 = 1.9783	65.25 = 2.5689	80.25 = 3.1594	95.25 = 3.7500	110.25 = 4.3405	125.25 = 4.9311
5.50 = .2165	20.50 = .8071	35.50 = 1.3976	50.50 = 1.9882	65.50 = 2.5787	80.50 = 3.1693	95.50 = 3.7598	110.50 = 4.3504	125.50 = 4.9409
5.75 = .2264	20.75 = .8169	35.75 = 1.4075	50.75 = 1.9980	65.75 = 2.5886	80.75 = 3.1791	95.75 = 3.7697	110.75 = 4.3602	125.75 = 4.9508
6 = .2362	21 = .8268	36 = 1.4173	51 = 2.0079	66 = 2.5984	81 = 3.1890	96 = 3.7795	111 = 4.3701	126 = 4.9606
6.25 = .2461	21.25 = .8366	36.25 = 1.4272	51.25 = 2.0177	66.25 = 2.6083	81.25 = 3.1988	96.25 = 3.7894	111.25 = 4.3799	126.25 = 4.9705
6.50 = .2559	21.50 = .8465	36.50 = 1.4370	51.50 = 2.0276	66.50 = 2.6181	81.50 = 3.2087	96.50 = 3.7992	111.50 = 4.3898	126.50 = 4.9803
6.75 = .2657	21.75 = .8563	36.75 = 1.4468	51.75 = 2.0374	66.75 = 2.6279	81.75 = 3.2185	96.75 = 3.8090	111.75 = 4.3996	126.75 = 4.9901
7 = .2756	22 = .8661	37 = 1.4567	52 = 2.0472	67 = 2.6378	82 = 3.2283	97 = 3.8189	112 = 4.4094	127 = 5.0000
7.25 = .2854	22.25 = .8760	37.25 = 1.4665	52.25 = 2.0571	67.25 = 2.6476	82.25 = 3.2382	97.25 = 3.8287	112.25 = 4.4193	
7.50 = .2953	22.50 = .8858	37.50 = 1.4764	52.50 = 2.0669	67.50 = 2.6575	82.50 = 3.2480	97.50 = 3.8386	112.50 = 4.4291	
7.75 = .3051	22.75 = .8957	37.75 = 1.4862	52.75 = 2.0768	67.75 = 2.6673	82.75 = 3.2579	97.75 = 3.8484	112.75 = 4.4390	
8 = .3150	23 = .9055	38 = 1.4961	53 = 2.0866	68 = 2.6772	83 = 3.2677	98 = 3.8583	113 = 4.4488	
8.25 = .3248	23.25 = .9153	38.25 = 1.5059	53.25 = 2.0965	68.25 = 2.6870	83.25 = 3.2776	98.25 = 3.8681	113.25 = 4.4587	
8.50 = .3346	23.50 = .9252	38.50 = 1.5157	53.50 = 2.1063	68.50 = 2.6968	83.50 = 3.2874	98.50 = 3.8779	113.50 = 4.4685	
8.75 = .3445	23.75 = .9350	38.75 = 1.5256	53.75 = 2.1161	68.75 = 2.7067	83.75 = 3.2972	98.75 = 3.8878	113.75 = 4.4783	
9 = .3543	24 = .9449	39 = 1.5354	54 = 2.1260	69 = 2.7165	84 = 3.3071	99 = 3.8976	114 = 4.4882	
9.25 = .3642	24.25 = .9547	39.25 = 1.5453	54.25 = 2.1358	69.25 = 2.7264	84.25 = 3.3169	99.25 = 3.9075	114.25 = 4.4980	
9.50 = .3740	24.50 = .9646	39.50 = 1.5551	54.50 = 2.1457	69.50 = 2.7362	84.50 = 3.3268	99.50 = 3.9173	114.50 = 4.5079	
9.75 = .3839	24.75 = .9744	39.75 = 1.5650	54.75 = 2.1555	69.75 = 2.7461	84.75 = 3.3366	99.75 = 3.9272	114.75 = 4.5177	
10 = .3937	25 = .9842	40 = 1.5748	55 = 2.1653	70 = 2.7559	85 = 3.3464	100 = 3.9370	115 = 4.5275	
10.25 = .4035	25.25 = .9941	40.25 = 1.5846	55.25 = 2.1752	70.25 = 2.7657	85.25 = 3.3563	100.25 = 3.9468	115.25 = 4.5374	
10.50 = .4134	25.50 = 1.0039	40.50 = 1.5945	55.50 = 2.1850	70.50 = 2.7755	85.50 = 3.3661	100.50 = 3.9567	115.50 = 4.5472	
10.75 = .4232	25.75 = 1.0138	40.75 = 1.6043	55.75 = 2.1949	70.75 = 2.7854	85.75 = 3.3760	100.75 = 3.9665	115.75 = 4.5571	
11 = .4331	26 = 1.0236	41 = 1.6142	56 = 2.2047	71 = 2.7953	86 = 3.3858	101 = 3.9764	116 = 4.5669	
11.25 = .4429	26.25 = 1.0335	41.25 = 1.6240	56.25 = 2.2146	71.25 = 2.8051	86.25 = 3.3957	101.25 = 3.9862	116.25 = 4.5768	
11.50 = .4528	26.50 = 1.0433	41.50 = 1.6339	56.50 = 2.2244	71.50 = 2.8150	86.50 = 3.4055	101.50 = 3.9961	116.50 = 4.5866	
11.75 = .4626	26.75 = 1.0531	41.75 = 1.6437	56.75 = 2.2342	71.75 = 2.8248	86.75 = 3.4153	101.75 = 4.0059	116.75 = 4.5964	
12 = .4724	27 = 1.0630	42 = 1.6535	57 = 2.2441	72 = 2.8346	87 = 3.4252	102 = 4.0157	117 = 4.6063	
12.25 = .4823	27.25 = 1.0728	42.25 = 1.6634	57.25 = 2.2539	72.25 = 2.8445	87.25 = 3.4350	102.25 = 4.0256	117.25 = 4.6161	
12.50 = .4921	27.50 = 1.0827	42.50 = 1.6732	57.50 = 2.2638	72.50 = 2.8543	87.50 = 3.4449	102.50 = 4.0354	117.50 = 4.6260	
12.75 = .5020	27.75 = 1.0925	42.75 = 1.6831	57.75 = 2.2736	72.75 = 2.8642	87.75 = 3.4547	102.75 = 4.0453	117.75 = 4.6358	
13 = .5118	28 = 1.1024	43 = 1.6929	58 = 2.2835	73 = 2.8740	88 = 3.4646	103 = 4.0551	118 = 4.6457	
13.25 = .5217	28.25 = 1.1122	43.25 = 1.7028	58.25 = 2.2933	73.25 = 2.8839	88.25 = 3.4744	103.25 = 4.0650	118.25 = 4.6555	
13.50 = .5315	28.50 = 1.1220	43.50 = 1.7126	58.50 = 2.3031	73.50 = 2.8937	88.50 = 3.4842	103.50 = 4.0748	118.50 = 4.6653	
13.75 = .5413	28.75 = 1.1319	43.75 = 1.7224	58.75 = 2.3130	73.75 = 2.9035	88.75 = 3.4941	103.75 = 4.0846	118.75 = 4.6752	
14 = .5512	29 = 1.1417	44 = 1.7323	59 = 2.3228	74 = 2.9134	89 = 3.5039	104 = 4.0945	119 = 4.6850	
14.25 = .5610	29.25 = 1.1516	44.25 = 1.7421	59.25 = 2.3327	74.25 = 2.9232	89.25 = 3.5138	104.25 = 4.1043	119.25 = 4.6949	
14.50 = .5709	29.50 = 1.1614	44.50 = 1.7520	59.50 = 2.3425	74.50 = 2.9331	89.50 = 3.5236	104.50 = 4.1142	119.50 = 4.7047	
14.75 = .5807	29.75 = 1.1713	44.75 = 1.7618	59.75 = 2.3524	74.75 = 2.9429	89.75 = 3.5335	104.75 = 4.1240	119.75 = 4.7146	

Chart courtesy EMPI.

Tuning Recommendations

Most modified engines never produce the horsepower of which they are capable because their builders fail to spend the extra effort required to make their creations run perfectly. You can make your investment pay maximum dividends through careful attention to details during assembly – and then tuning it to perfection after you have installed it – or on an engine dyno. $10 to $30 worth of chassis or engine-dyno time will produce far more performance than you might imagine.

Items which deserve special attention include carburetor jetting, linkage, and synchronization (for dual carbs). Ignition timing – initial setting and centrifugal-advance rate and amount – is another area of importance. Transmission and rear-axle ratios must also be carefully selected to get the desired performance.

Multiple-carb installations do not stay synchronized, so buy a Uni-Syn or other synchronizing tool – and use it frequently. Prior to any tuning or competition efforts, check that the carb linkage works easily to open the carbs fully and close them positively with no binding or sticking. This kind of action is well worth whatever time it takes to make it happen.

No gaskets should obstruct the carbs at their bases or the manifold castings where they join the heads.

Selection of the correct jets can be accomplished by observing the color of the porcelain insulators. However, new plugs may take time to "color" – so use an illuminated magnifier (Champion or A-C tool) to make this chore an easier one. These illuminate the base of the porcelain where it is buried in the plug shell. Because this is the first part of the plug to "color, the magnifier should be considered an essential tool for any racer's toolbox.

Plug color is only meaningful when the engine is declutched and the ignition "cut" at the end of a high-speed full-throttle, high-gear run. If you allow the car to slow down with the engine still running, plug readings become meaningless. Plug readings can be made after a full-throttle run on a chassis dyno with the transmission in an intermediate gear, but the same does not hold true for road tests, which must be made in high gear. Similarly, plug checks can be made where the engine has been running against full load at full throttle on an engine dyno.

When you have installed the jets which give maximum performance (12:1 air:fuel ratio), you may have less economy than you'd like for daily driving. Should this be the case, use leaner jets for around-town driving and highway use – remembering that the engine is being fed a too-lean mixture for full-throttle operation. Re-jet the carbs when it's time to race. Part-throttle and cruise air/fuel ratios are usually set for 14 or 15:1 – or even leaner on many cars which are set up for minimum emissions.

Air cleaners can affect mixture, especially on the VW, so run your tests with the air cleaner/s installed. Dyno tests with and without the cleaners can quickly show whether the air cleaners are restrictive.

Set the ignition timing per factory specs, using added initial advance with caution as described in the chapter on ignition. Avoid setting the timing while the engine is being tested on a chassis or engine dyno – sometimes called "power timing" unless you load the engine long enough for the temperatures to stabilize. Flash readings made in conjunction with quick twisting of the distributor to get impressive readings are not the answer. Should you do this, and then run the engine with the same setting – especially at high speeds on the road or in competition – you can destroy the engine. I know this from bitter personal experience. Here's what happens – the spark setting which can be tolerated by the engine during a flash reading before spark-plug and cylinder-head temperatures have stabilized is more advanced than the engine can safely use after temperatures have reached the higher values in steady operation. As a result, the dyno setting of ignition timing for the highest flash reading will always be too far advanced. Using such settings for anything more than a quick blast through the quarter-mile will cause destructive detonation.

Tuning pays off in performance dividends. This is true with any engine, whether it is stock or highly modified. You may not have access to a dyno. Even so, you can do a lot of tuning on the road with a stop watch. Select a length of road without traffic and with easy-to-see markers. Keep detailed records in a notebook – and *never change more than one thing at a time.* You'll be surprised at how accurately you can spot what is helping – or hindering – your car's performance. You can equalize air-density effects by testing during the coolest part of the day – and preferably on days with similar barometric pressures.

While it is especially tempting to tune by the "seat of your pants," stopwatches and dynamometers are more meaningful indicators of what progress you are making in your tuning efforts when you are trying to get your car ready to win trophies at the drags or autocrosses.

PLUG COLOR CHART

Rich - Sooty or wet plug bases, dark exhaust valves.

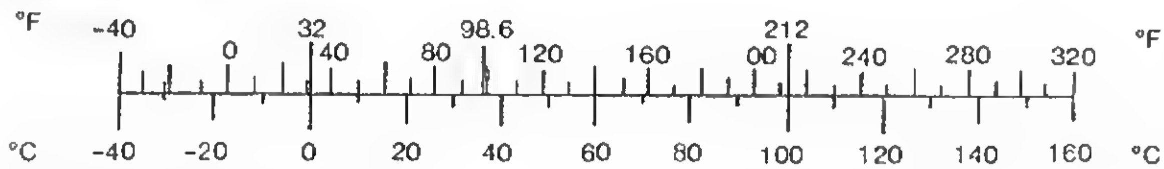
Correct - Light-brown color on porcelains, exhaust valves red-brown clay color. Plug base slightly sooty (leaves slight soot mark on hand when plug base turned against palm). New plugs will start to color at the base of the porcelain and this is only visible with an illuminated plug magnifier.

Lean - Plug base ash grey. Glazed-brown appearance of porcelain may also indicate too-hot plugs. Exhaust valves whitish color.

METRIC/CUSTOMARY-UNIT EQUIVALENTS

Multiply:		by:		to get:	Multiply:	by:		to get:
LINEAR								
inches	X	25.4	=	millimeters(mm)	X	0.03937	=	inches
feet	X	0.3048	=	meters (m)	X	3.281	=	feet
miles	X	1.6093	=	kilometers (km)	X	0.6214	=	miles
AREA								
inches^2	X	645.16	=	millimeters^2(mm^2)	X	0.00155	=	inches^2
feet^2	X	0.0929	=	meters^2(m^2)	X	10.764	=	feet^2
VOLUME								
inches^3	X	16387	=	millimeters^3(mm^3)	X	0.000061	=	inches^3
inches^3	X	0.01639	=	liters (l)	X	61.024	=	inches^3
quarts	X	0.94635	=	liters (l)	X	1.0567	=	quarts
gallons	X	3.7854	=	liters (l)	X	0.2642	=	gallons
feet^3	X	28.317	=	liters (l)	X	0.03531	=	feet^3
feet^3	X	0.02832	=	meters^3(m^3)	X	35.315	=	feet^3
MASS								
pounds (av)	X	0.4536	=	kilograms (kg)	X	2.2046	=	pounds (av)
FORCE								
pounds—f(av)	X	4.448	=	newtons (N)	X	0.2248	=	pounds—f(av)
kilograms—f	X	9.807	=	newtons (N)	X	0.10197	=	kilograms—f

TEMPERATURE



Degrees Celsius (C) = 0.556 (F - 32)

Degrees Fahrenheit (F) = (1.8C) + 32

Multiply:		by:		to get:	Multiply:	by:		to get:
PRESSURE OR STRESS								
inches Hg (60F)	X	3.377	=	kilopascals (kPa)	X	0.2961	=	inches Hg
pounds/sq in.	X	6.895	=	kilopascals (kPa)	X	0.145	=	pounds/sq in
POWER								
horsepower	X	0.746	=	kilowatts (kW)	X	1.34	=	horsepower
TORQUE								
pound-inches	X	0.11298	=	newton-meters (N-m)	X	8.851	=	pound-inches
pound-feet	X	1.3558	=	newton-meters (N-m)	X	0.7376	=	pound-feet
pound-inches	X	0.0115	=	kilogram-meters (Kg-M)	X	87	=	pound-inches
pound-feet	X	0.138	=	kilogram-meters (Kg-M)	X	7.25	=	pound-feet
VELOCITY								
miles/hour	X	1.6093	=	kilometers/hour(km/h)	X	0.6214	=	miles/hour
kilometers/hr	X	0.27778	=	meters/sec (m/s)	X	3.600	=	kilometers/hr

COMMON METRIC PREFIXES

mega	(M)	=	1,000,000	or	10^6	centi	(c)	=	0.01	or	10^{-2}
kilo	(k)	=	1,000	or	10^3	milli	(m)	=	0.001	or	10^{-3}
hecto	(h)	=	100	or	10^2	micro	(μ)	=	0.000,001	or	10^{-6}

Conversion chart courtesy of Ford Motor Company.

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